Intensification of cropping systems under rainfed farming in the Western Usambaras, Tanzania

- Alternatives and Options -

Johannes Kotschi

April 1997

Consultancy for SECAP/GTZ Lushoto, Tanzania

Table of Contents

1. Introduction

1.1 Scope of the consultancy

From 11th of February to 4th of March 1997 a consultancy on "alternative cropping systems" was carried out on behalf of the Soil Erosion and Agroforestry Project (SECAP) in Lushoto. It should cover the four divisions of the district Soni, Lushoto, Mtae and Mlalo, in which SECAP is working.

The consultancy was thought to be a first step towards the Output No. 1 of the present project phase (1996-2000) which was formulated during the planning workshop in November 1995 as follows: "Economically viable soil and water conservation (SWC), agroforestry (AF), crop and animal husbandry options which can be integrated into various farming systems are available."

To achieve this output the following activities were defined:

"... i. Determine costs of establishing and maintaining SWCM.
ii. Identify further agroforestry, crop and animal husbandry options to combine with SWCM.
iii. Scrutinise options mentioned under ii.) for their suitability for various farming systems.
iv. Assess economic viability and market potentials of options under ii).
v. Develop extension materials to promote economically viable agroforestry, crop and animal husbandry options.
vi. Improve cooperation with relevant organization (TSDDP, TIP) to facilitate promotion of crop and animal husbandry options.
vii. Monitor economic viability of farm enterprises with SWCM compared to farm enterprises without SWCM....."

The consultancy covered mainly the activities ii) and iii). The detailed terms of reference are listed in annex VII.

In order to achieve the required results all existing studies, reports and other SECAP related publications of the past 16 years were reviewed. In addition, an extensive informal farmer survey was carried out. Over 6 days male as well as female farmers were interviewed, their knowledge and attitudes towards numerous innovations in the cropping system were assessed. The information was reviewed an evaluated on the basis of existing experience and scientific knowledge at comparable agro-ecological sites namely Machakos/Kenya and Nyabisindu/Rwanda. The results are summarized in the following report.

1.2 The data base

Despite an impressive wealth of documents there is a general lack of data from the region. German funded projects such as LIDEP, TIRDEP and finally SECAP worked in Lushoto District over a period of approximately 25 years. But there are only few data on soil characteristics as well as on crop and animal husbandry. Since the Beginning of TIRDEP it has been frequently proposed to conduct supplementary research and data assessment in Lushoto District and many attempts have been undertaken.

During the period of 1985-1988 thorough research was carried out and is well documented (Pfeiffer 1990). However, it turned out that results have little relevance for the promotion of the present cropping systems. Pfeiffers work concentrated mainly on the development of the "macro contour line (mcl)" and farmer´s practice has meanwhile proven that this technology is not a viable perspective. In addition most of Pfeiffers results were obtained on the demonstration fields of SECAP. These fields are situated on lower slope positions with relatively good soil productivity, better water supply and less erosivity than most fields. Therefore, they are of limited relevance for most fields of the farms.

Since 1988 numerous field trials have been planned and started, but the outcome of all of these trials is disappointing. Many of them were started but not fully implemented, the analysis and interpretation of data is generally missing and no results can be used from these trials.

Therefore, an a physical and economical evaluation of the present cropping systems and proposals for options and alternatives based on solid physical assumptions or economic calculations was not possible. Instead, the findings and conclusions in this report derive from qualitative and descriptive parameters. They evolved from numerous observations in the field, farmers partly surprising opinions and attitudes and many discussions with project staff. The original idea to make an economic assessment had to be given up.

2. Justification for the focus on rainfed farming

Like many tropical mountain areas Lushoto District represents a multitude of cropping patterns and their different combination form a wide range of farming systems. The crops grown depend mainly on the climate and of the topography of a specific site.

With respect to climate the SECAP intervention area can be roughly divided into three agro-ecological zones (table 1):

* Zone I, which is humid warm and concerns mainly the division of Soni,
* Zone II, which can be described as dry cold and extends over the division of Mtae, and
* Zone III, which is dry and warm and can be found in the division of Mlalo.

Table 1: Agro-ecological zones of the SECAP intervention area

Region		Altitude (m a.s.l.)	average annual precipitation (mm)	average daily temperature (°C)
I.	humid-warm	800 - 1,500	1,000 - 1,400	18
II.	dry cold	1,700 - 2,100	500 - 650	16
III.	dry warm	800 - 1,800	500 - 800	20

Source: Pfeiffer (1990) and Baum et al. (1983)

With respect to topography the crops in Lushoto District can be divided into two groups: Vegetables such as cabbage, tomatoes, peppers, irish potatoes and many others are grown in the valley bottom and on terraced land with additional irrigation. Vegetables are mainly grown for sale and the question of optimal marketing is more important than improving the cropping system.

In contrast to this, subsistence based food crops are cultivated on slopes and under rainfed farming. They comprise mainly maize, beans and a few other crops of minor importance mainly on slopes and under rainfed farming. In the past the land under rainfed farming was frequently exploited for the sake of further improving cash crop production in the valley bottoms and under irrigation: fodder was produced on the slopes and crops were grown, but little organic matter was returned to the same field. It was rather applied on the fields under irrigation, which promised a higher revenue. Today it can be observed that the cropping area on sloping land is decreasing. The steepest slopes which were taken under cultivation in the late seventies/early eighties are being abandoned. At the same time the remaining land is undergoing intensified land use. Increased efforts in soil and water conservation combined with an increase in manure application on terraced land is an indicator for it.

Coming back to the question: "Which options do exist to further intensify in a sustainable way the present farming systems?" The answer, being the working hypothesis of this consultancy, is: the main potential for further intensification is to be found with the cropping systems under rainfed farming by using improved techniques on soil and water conservation and improved methods on soil fertility maintenance. Accordingly, this study concentrates on ways and means how to intensify this sector. Three aspects are being discussed: soil and water conservation, soil fertility maintenance and the presently grown crops.

Based on experiences of other sites (mainly Nyabisindu Rwanda) it was decided to diversify and enlarge this technology. The grassline was supplemented by deep rooting legume shrubs, as well as ground covering legumes. Intensive research was carried out (Pfeiffer 1990) and "macro-contour lines" tailored for different agro-climatical sites were developed. Experimental results proposed an enormous increase in productivity a boost in fodder supply and milk as well as manure production. An economic evaluation suggested high benefits.

But the technology was never accepted. Farmers considered the macro-contourline as being too sophisticated, as requiring too much land. At the same time it became obvious that the farmer´s readiness to plant Guatemala grass strips decreased with decreasing subsidies by SECAP. Farmers complained about this species: "it is too demanding on soil nutrients", "rats do inhabitate it" and "the process of terracing (approximately 0,1 m/year) is too slow". It also became evident, that farmers did not invest in their sloping land by applying regularly organic manure. In consequence the yield of the field crops and the grass strips decreased, the fields on sloping land became less and less productive and maintaining the grass strips was no longer considered worthwhile. Grass strips became more and more patchy, and only very few new strips were established.

A change of technologies took place when the Traditional Irrigation Project (TIP) promoted bench terracing for irrigable fields. The bench terraces evolved to be quite a success and soon they where also applied on sloping land under rainfed farming. Since 1993 bench terraces and to a smaller degree *Fanya juu* terraces are constructed in on a larger scale in all 4 divisions, where SECAP is working. This success of a technology with an enormous labor input seemed quite surprising. What is the reason behind?

Bench terraces obviously enable a considerable increase in productivity of land. It is mainly caused by water harvesting. Bench terraces, combined with infiltration drains can collect all rainfall, whereas contour strips only reduce the surface run-off. Applying moderate quantities of manure in addition, enormous yield increases can be achieved. In comparison to non-terraced land the difference in yield increases with the steepness of slope.

Today different techniques on soil and water conservation (SWC) are recommended according to steepness of slope are recommended by SECAP:

* Contourlines/Macrocontourlines up to 12 % of slope
* *Fanya juu* terraces between 12-35% of slope
* bench terraces between 35 - 55% of slope
* no more arable farming beyond 55% of slope

The labor input and the loss of cropping area of the different techniques are compiled in the following table.

Impact of bench terraces. No measurements have been carried out to determine the difference in yield and to quantify the economic benefit of soil conservation measures. Such a comparison would have to consider quite a number of variables. The most important are: differences in soil productivity, different water inflow from the upper slope, and differences regarding the steepness of slope. Last but not least rainfall variability has to be considered; The result in years of low and high rainfall will be quite different. Thorough research in this field would be quite complicated, expensive and would require at least a period of three years intensive work. Considering the financial and personal means of SECAP, there is no capacity to do it.

only 8% on terraced plots. The reduction of risk is a significant benefit, especially if one considers that in years of unreliable rainfall the production is generally low and the prices are high.

Options and alternatives. First of all a better stabilization of terraces seems very important. The coverage by grass should be denser and should cover the whole riser not only the upper edge of the terrace. Also a diversification of Napier grass would be desirable. Only few farmers use Bana grass as a second species. In addition, ground covering legumes should be included in the long run. A mixture of grasses and legumes could help increase the productivity of the riser and improve the quality of fodder produced.

Another aspect of concern is the steepness of the riser. It is in most cases 90° steep and sometimes even negative. Although clay rich soils allow the highest steepness of risers it should not excedd 70°.

A proper construction and maintenance of the terraces are of utmost importance. Taking the experience from Machakos, many terraces collapsed after a few years only, because they were not properly reinforced by vegetation.

Unsatisfying is also the participation of the beneficiaries in surveying the land. At present all measurements of the contourlines are carried out by "field assistants" with sophisticated instruments. They are employed and paid by SECAP. On several occasions it has been proposed, to work with the A-Frame instead. The A-Frame is a very simple and at the same time sufficiently precise instrument. But often technicians consider it as too primitive. More sophisticated equipment gives them more status and self-consciousness. This attitude is detrimental to teh estension of soil and water conservation. It has to be seen that field assistance can only survey a very limited acreage of land. Also, SECAP may come to an end by the year 2000. If the process of soil and water conservation shall continue, even without external support, it is very important to train farmers in measuring contour-lines with simple instruments. It is recommended that the field technicians are trained to work with the A-Frame and to calibrate it against their presently used instruments.

resources, by introducing stabling and fodder production. "Zero grazing" can be considered one of the most important innovations in the development of farming systems in the district. Also, the value of cattle has changed. In the past cattle were a means of investment, an indicator of wealth and social status and also of course a producer of milk and meat. During the farmer interviews many of them stated, that the production of manure is the most important objective for animal husbandry. There is a significant awareness of the importance of manure for maintaining soil fertility and many of them feel that they cannot get enough.

It is difficult to estimate the amount of animal manure available on an average farm. Again no data exist. Pfeiffer (1990) and Kotschi et al. (1991) suggest that the amount that can be produced by one adult cow (TLU) under stall keeping, is in the range of 6-10 t/year. The quantity depends on how much crop residues are given for bedding and it depends on the length of stallkeeping. Most of the farms, which were visited, revealed a rather poor practice in adding crop residues

The amount of manure which can be made available can roughly be estimated by the stocking rate in the district. For the year 1975 the Tanga Water Masterplan (Egger et al. 1980) calculated with 168.500 TLU[1] on 1.349 km^2 of total arable land, which represents 68,5% of the total area (1.970 km^2). This results in a stocking rate of 1.25 TLU/ha. "Initial Farmer Interviews" carried out by the project (SECAP 1994) 20 years later with 118 farmers in the villages Malindi, Mlesa and Shashui gave a very similar ratio. The average stocking rate was 1.39, 1.26 and 1.33 respectively. Accordingly, as an overall district average and based on the above mentioned figures with 1.25 TLU 12.5 t/ha+y can be produced. This corresponds with an amount of nutrients of approximately 80 kg N, 14 kg P, 120 kg K, 35 kg Ca and 20 kg Mg.

---

[1] TLU stands for Tropical Livestock Unit and represents one adult cow with a live weight of 250 kg.

Compost. Manure is seldom applied fresh to the field. In most cases it undergoes some kind of fermentation. Manure heaps with all stages of decomposition can be observed near the homesteads, and in practice there is no clear cut difference between manure and compost. In order to avoid a misunderstanding, the composted manure has to be distinguished from the understanding of SECAP staff who uses the term "compost" for material coming from crop residues.

There is no clear cut opinion about farmers, whether well composted or very rough "composts" are preferable. In most cases the compost is put on some kind of "heap" next to the cow-shed which may be a stall, an open place under a tree, or simply a roof, under which the cattle is tied with a rope, and the collection of manure on heaps or in pits is far from being done thoroughly. Cow dung is rather dumped next to the cow-place. Chicken and other animals are scratching in it, and the wind is distributing it. Generally there are considerable losses. Urine - another valuable source of nutrients (mainly nitrogen and potassium) is very rarely utilized and can only properly collected in stalls which have a cement floor. But this concerns only a small number of farms.

This carelessness is contradictory to the farmers´ conviction that they are always short of compost and keep animals mainly for the production of manure. In addition, this way of storage causes considerable losses of nutrients - mainly nitrogen - and constrains decomposition, because these heaps are completely dry. The technique of making compost has been propagated by SECAP right from the beginning. Only since recently compost pits can be observed with a few farmers in Mtai and Mlalo. It can also be observed that the training of the divisional staff on composting (KIOF/Kenya) gains momentum in farmer´s practice.

For a model calculation the amount and the nutrient content of well composted manure based on the above mentioned quantities can be given as follows. Based on trial results from Pietrowicz and Neumann (1987) nutrient losses by composting can be calculated for N 22%, for P 48% for K 14% for Ca 10 % and for Mg 7%, and a further reduction of losses through improved compost technology is possible. In the following table the respective nutrient doses are calculated.

Table 3: Nutrient content of fresh and composted manure

	Amount	N		P		K		Ca	
	kg/TLU+y	%	kg	%	kg	%	kg	%	kg
Fresh manure (30% H_2O)	12,500	1.68	210.00	0.28	35.00	2.33	291.25	0.73	91.25
Composted manure (10% H_2O	5,800	2.19	127.02	0.27	15.66	3.33	193.14	1.09	63.22

Source: Calculated from Pietrowicz & Neumann (1987), see also Table IV/4 and Müller-Sämann & Kotschi (1994). Taking the amount of fresh animal manure of 12.5 t/ha and considering 40% dry matter losses through fermentation and a reduction of the water content during the fermentation process from 30% to 10% 5.8 t/ha will remain. Nutrient losses through composting are assumed as follows: N 22%, P 48%, K 14%, Ca 10% and Mg 7%. This results in a dry matter nutrient content of 2.19% N, 0,27% P, 3.33% K, 1.09% Ca.

Transport of composted manures to the field. The problem that manures are not returned to sloping land where the fodder comes from and in particular to the more distant fields was identified quite early. One reason is without doubt, that this transport is very labor-intensive. Consequently, SECAP undertook several efforts to find technical solutions to ease this burden (wheel barrows, cow-carts), but with little success. Until today manure/compost is carried as a head-load in buckets and baskets to the field by family members or by hired labor. Headloads are carried to the field every time somebody goes to the field provided there is additional carrying capacity. Composted manure is even transported over more than 1 km if considered it useful/profitable. The transport lasts over a period of 4-6 weeks before planting. Small heaps, uncovered and exposed to the sun and to rainfall wait for incorporation and further losses of nutrients are inevitable.

It is obvious, that distant fields are generally less fertilized than near-by ones. But distance is not an insurmountable contstraint. The main motive to fertilize or not is: "does it pay?". With the construction of bench terraces and the possibility of reducing run-off water to almost zero the combination of compost and improved water supply result in yield increases that make the application of composted manure attractive, even if it has to be transported over longer distances and without mechanical support such as wheel barrows or cow-carts. There is growing evidence that under bench terraces the application of manure on sloping land has increased.

Quantities applied can be measured in buckets. Per hole approximately 3 "cups" are applied. 1 bucket contains 10-25 kg of manure resulting in an average of approximately 17kg. Farmers asked on how much they apply to their newly conserved fields resulted in amounts between 22 - 28 t/ha.

Options and alternatives. There is a large potential for the improvement of manures. Both quantity and quality can be increased considerably. First of all the amount of material to be composted should be increased by more careful collection of all organic residues from animals (dung and urine) and crops. In addition, small amounts of soil should be added. Also, an improved feeding practice may have a positive effect on the amount of dung produced. At present fodder grasses and other feeds are given as whole parts. By chopping it into small pieces the fodder uptake and the dung output could probably be increased.

Secondly, the losses of dry matter and of nutrients could be reduced considerably with an appropriate storage and compost technology. It is recommended to advise the farmers on pit composting in zones II and III, and on heap composting in zone I. All the technological improvements in manure production, in composting and in the application of composted manure require careful extension and training. But research in this field is not necessary.

4.2 Agroforestry

A second important innovation beside zero grazing is the farmers´ practice to raise trees. 15 years ago there was almost no tree raising at all, except for a few fruit trees near the homestead. The practice of raising trees is evidenced by many young trees on farmers´ fields, woodlots and on hill tops which were bare a few years ago. Today trees are planted along field borders and in the fields. Many hills and slopes have changed their visual appearance. If the number of trees would be counted for instance by air photo interpretation by comparing the late seventies and the situation of today it would confirm that the number of trees has increased considerably.

Grevillea robusta has become the most popular tree. Its fast and erect growth provides poles for construction in good quality in a relatively short period of time. It has a high litter fall which is well appreciated as a valuable source of mulch and nutrients on the fields. Its crown can be pruned to a small and erect shape by which shading of undergrown crops can be reduced considerably.

In practice a wide range of tree densities on the fields do exist; despite an enormous overall increase there is still a considerable percentage of arable land with no trees. The farms who practice agroforestry have mostly a rather low tree density, by which the potential for agroforestry is under-utilized. Only in a few exceptional cases a too high number of trees was found. A point of concern is the overall dominance of *Grevillea robusta.* It contains the risk that a possible disease or pest which may come up and specifically attack Grevillea could become a disaster. The percentage of other trees in agroforestry systems is low, probably less than 15%, and there are only a few recommendable species namely *Acrocarpus fraxinifolius, Albizzia schimperiana, Markhamia, Leucaena diversifolia and Calliandra callothyrsus.*

Based on research findings from similar sites (Neumann & Pietrowicz 1985) a suitable tree density with *Grevillea robusta* would be 250 trees/ha with a cropping cycle of 9-

10 years. In a field trial in Rwanda such a tree density raised the crop yield (related to the total area) despite a loss of cropping area and the trees gave a high additional yield in kind of timber, mulching material and firewood (see also table IV.14). This increase in land-productivity is explained by better use of water (reduced surface run off and reduced evapotranspiration per unit of biomass produced) and by the fertilizing effect of the *Grevillea* leaf fall (Kotschi et al 1991). With 250 trees and a 9-year cropping cycle (by which one ninth of the trees is harvested and every year replanted). Assuming a leaf litter fall of 6 t/ha+y and an additional 1t/ha+y (dry matter) of leaves from the trees felled every year this would result in the following amounts of nutrients (see also tables IV.11 and IV.12): 60 kg N, 0.63 kg P, 28 kg K, 98 kg Ca and 8.4 kg Mg. This is a considerable amount and it explains why many farmers value the high litter fall of *Grevillea.*

Options and alternatives. It is recommended that the number of trees is increased up to 250 per ha and with a cropping cycle of 9-10 years. At the same time it should be propagated to diversify *Grevillea* stands with *Acrocarpus, Albizzia and Markhamia.*

4.3 Green manuring

Since ancient times green manuring to enhance soil fertility is widely practiced in different agro-ecological zones of the tropics (King 1911, FAO 1979, Ludwig 1967). In the Usambara Mountains the technology of green manuring is unknown, but a few plants suitable for green manuring do exist: a local cultivar of *Dolichos lablab* (Hyacinth bean, Lablab purpureum) and single plants of *Cajanus cajan* are to be found on farms in all divisions.

Green manure in its original sense and applied in temperate climates implies that the plant material grown is incorporated as green matter into the soil. This practice is rarely found at tropical sites. Here, other techniques are applied: mainly intensive fallowing and undersowing. Under **intensive fallowing** land is taken out of production. The crop should consist of fast growing species - namely legumes and grown in mixtures - that can regenerate the soil in a short period of time. Intensive fallows of half a year to 3 years are known. Extensive experience in Nybisindu/Rwanda and in Cameroon suggests that intensive fallowing is an innovation not easy to introduce, and it is rarely accepted on productive fields as a measure of regular soil fertility maintenance. In this case no production can be achieved during the fallowing period. Better changes for intensive fallowing are given if used for the rehabilitation of degraded land which has been discarded for production. Considering the enormous scarcity of land in the Usambaras, and the basic problems in crop production which are still unsolved, there seems to be little potential for the introduction of intensive fallowing for the time being.

A third group of green manuring is known as **undersowing**. Ground covering legumes are undersown for instance in maize or sorghum. In shading the ground and producing additional biomass they reduce the mineralization of humus and add organic matter to the soil, and substantial quantities of nitrogen can be fixed. What seems to be more important under farm economic aspects is that quite a number of legumes can also be used as animal feed. *Dolichos lablab* - already known by quite a number of farms and cultivated in small supply has proven quite suitable. It grows well in Soni and Mlalo division, whereas temperatures of Mtae are too low. Dolichos combines quite a number of positive attributes: Its beans are appreciated as food ("it tasts as good as phaseolus beans and is high yielding") and provides an excellent animal feed. Dolichos is particularly fast growing. Crowder (1960 reports 25 t/ha of green material after 4-6 months growth in Columbia, in Brazil 35 t/ha were obtained in a mixed crop of Dolichos under maize. Besides its nodules from nitrogen fixation it also can supply large amounts of nitrogen by leaf decay. At Sao Paulo/Brazil Lambert (cit. in Skerman 1977) estimated maximum fixation rates of 220 kg/ha+year. In the Usambara Mountains its performance will be much less mainly due to the soil´s low content in available phosphorus. A more comprehensive description of Dolichos is given in annex V.

Options and alternatives. It is obvious that the balance of humus and nitrogen in the soil can be improved significantly by Dolichos and there are quite a number of arguments which could make the promotion of Dolichos a success: It can supply valuable food and animal feed at the same time, it is already known by farmers and it has an excellent impact on soil-fertility (humus and nitrogen). Its propagation is therefore recommended in Soni and Mlalo division. It should be planted as a relay intercrop in maize.

4.4 Mineral fertilizers

Again and again it has been discussed in SECAP whether mineral fertilizers would be an appropriate means to replenish the nutrient depleted soils under rainfed farming and mainly on slopes. At present they are virtually not applied on crops under rainfed farming, whereas under vegetable production in the valley bottoms and on irrigated land mainly urea (nitrogen) is given as a top-dressing.

No data on the impact of mineral fertilizers are available. From comparable sites e.g. Rwanda (Kotschi et al. 1991) it is well known, that NPK alone has very little effect on acid soils with a pH of 4.7 and less. Only in combination with doses of calcium or manure moderate yield increases are possible (Neel 1974, ISAR 1988). But these yield increase rarely compensate the higher costs. Farmers in Mlalo and Soni stated that with the present ratio of input costs and output prices under rainfed farming the use of mineral fertilizer is not economical, and one farmer, who compared the costs and benefits of manure and of urea over two years stated that using manure is less costly, although the longterm effects of manure were not included in the comparison. Technically spoken a priority issue would be to reduce soil acidity and phosphorus deficiency by adding phosphorus and calcium to the soil. Calcium phosphates with medium solubility would have a longterm effect and would avoid that a high proportion of soluble phosphorus is immediately fixed by aluminum and iron ions.

Options and alternatives. Subsidized sales of P and Ca fertilizers would be highly desirable. But it is unlikely that the government will be in a position to do so in the near future. Also, the farmers should be informed that the present practice to use solely nitrogen (e.g. urea) is quite detrimental to soil productivity as it increases acidification in the long run.

4.5 Resume

In the following paragraph a nutrient budget estimation is presented. It is calculated on the basis of a cropping system in which all the proposed improvements on soil fertility maintenance except for mineral fertilizer are included. The latter is left aside, because it seems doubtful whether this is a real option for the farms. This nutrient budget calculation may give an indication how the soil nutrient status may develop over longer periods. The figures demonstrate that there is a deficiency for N, P and K. Nitrogen can be replenished by microbial fixation. The deficiency of K is also of minor importance, because the soils are fairly rich in potassium. The problem that really counts is the deficiency of available phosphorus. Important in this context is the attribute "available". In fact soils are not completely lacking phosphorus, but due to the low pH in the range of 4.5 to 4 (H_20) most of it is fixed in the soil as aluminum and iron-phosphates. Therefore, measures that can help solve theproblem must not only consider to replenish phosphorus, more important is the addition of calcium to raise the pH. The following measures are proposed:

a) apply phosphate fertilizers. They should have low solubility (citrate soluble) such as Di-Calciumphosphate, Calcium-Meta-Phosphate and basic slag and rock-phosphate. Low solubility guarantees a slow release of P to the plant root, avoids fixation as Al- and Fe-phosphates;

b) apply calcium to raise the pH; in this respect it is noteworthy that the Ca-budget of the above calculation is positive. A slow - although very moderate - enrichment of Ca in the topsoil by agroforestry is given, but it is not sufficient to raise the low pH-values.

c) increase the biological activity of soils. High biological activity contributes in numerous ways to the mobilization of phosphorus. Mycorrhizal fungi, for example, are able deliver phosphorus from plant litter or from the vicinity of slow-release phosphorus sources directly to the plants. The enzyme activity of decomposing micro-organisms also contributes to the breakdown of P. Also largely dependent on biological activity is the very slow dissolution process of relatively stable, adsorbed phosphorus, derived primarily from the exchange of OH^-, HCO_3^- and organic anions formed through microbial activity and root exudates (Scheffer and Schachtschabel 1982). This was confirmed in recent studies at the Centro Internacional de Agricultura Tropical (CIAT) in Colombia, in which it was found that phosphorus hitherto considered unavailable to plants is in fact released from Fe-Al compounds through these biological activities (Sanches and Salinas 1981).

There is no ultimate and clear cut answer to solve the problem. A strategy which aims at increasing soil fertility has to focus on the alleviation of soil acidity and improving the amount of available phosphate. In order to achieve this all three measures should be combined. Agroforestry, manure application and Ca als well as P-Fertilizers have to be applied in a joint effort.

Table 4: Top soil nutrient budget (kg/ha+y)

- a model calculation -

	N	P	K	Ca
Possible Input				
Manure[1]	31.8	3.9	48.3	15.8
Litterfall of Grevillea[2]	30	0.32	14	49
Subtotal input	61.80	4.22	62.30	64.80
Possible output: Crop removal and other losses				
Maize grain[3]	25.2	6.1	7.2	0.2
Maize stover	17.7	3.8	35.4	9.0
Phaseolus[3] beans	18.0	3.0	10.0	0.1
Phaseolus crop residues	9.4	1.0	11.8	4.5
Grevillea trees[4]	6.7	1.3	4.0	13.3
grass strips[5]	25.5	1.0	26.0	3.9
leaching losses[6]	2.16	0.34	1.99	0.65
subtotal	104.66	16.54	96.39	31.65
balance	-42.86	-12.32	-34.09	33.15

Assumptions:

[1] 22 t/ha composted manure can be applied once in 4 years; nutrient content according to calculation in table 3.

[2] Calculation based on findings in Rwanda (Neumann & Pietrowicz (1985); see also table IV.11. Assuming a leaf litter fall of 6 t/ha+y and an additional 1t/ha+y (dry matter) of leaves from the trees felled every year this would result in the following amounts of nutrients (see also table y): 60 kg N, 0.63 kg P, 28 kg K, 98 kg Ca and 8.4 kg Mg. It is assumed that 50% derives from deeper soil layers and additional nitrogen assimilation respectively.

[3] calculated from Storvogel and Smaling (1990, cited in Mukeni 1992) and de Geus (1974)

[4] the nutrient content of Grevillea wood is estimated on the basis of average values as given by Feger (1993) with: 0,1% for N, 0.02% for P, 0.06% for K and 0.2% for Ca. 1 m^3 of Grevillea wood is calculated with 600 kg dry matter and the dry matter content of branches is calculated with 65%. The wood production is based on the findings of Neumann and Pietrowicz for Rwanda (Kotschi et al. 1991); see also table IV.14

[5] for the grass production a yield of 30 t/ha+y with a dry matter content of 50% is assumed; the cropping area is calculated with 10%. The nutrient content is based on the findings of Pfeiffer (1990) for Tripsacum laxum with: 1.71 for N, 0.07% for P, 1.73% for K and 0.26% for Ca.

[6] under organic manuring in small quantities leaching losses are minimal, they are accounted for 2% of total losses. Atmospheric losses are neglected.

5. Crops

5.1 Food crops

In search of possible options on how to intensify rainfed farming in Lushoto District it has also to be asked, up to which extent agronomical innovations can contribute to it. The main food crops concerned are maize and beans; crops of minor importance are: irish potatoes, cassava, sweet potatoes and wheat. Again, for all crops there was only little information available.

The most important crop is **maize**. The agricultural statistics of the district suggests that its cropping area has decreased from 40-50,000 ha in the late seventies and early eighties to 15-20,000 ha in the nineties. If this holds true, it would be important to know whether maize has been replaced by another crop and by which, or whether the total cropping area has decreased - a question which could not be answered in the context of this study. Concerning the yields per ha there is little reliable information and obviously a wide range can be found. Yields vary from 500 kg/ha up to more than 2000 kg/ha. One reason for this big difference is that the climatic conditions are very variable. In the dry-warm climate (Mlalo) local varieties can mature in 3-4 months and give low yields, under humid warm conditions (Soni) it takes 5-6 months and under dry cold conditions (Mtae) it may take even more than 6 months, and the high altitude sites of Lushoto division are too cold for maize cultivation during the long rains. In Lushoto maize is often replaced by irish potatoes.

Therefore, a concept on improving maize cultivation would require a very differentiated approach and an intensive screening program on-farms at the different sites of the district. If this is possible it would be worth while to test improved varieties of the Katumani type and others. The screening of new varieties should concentrate on higher yield potential and early maturity.

Beans are a staple food and as important as maize. They are mostly intercropped with maize, sometimes planted simultaneously, sometimes earlier. A potential for improvement is seen by using new varieties of the climbing type. The CIAT bean-program offers a range of quite productive varieties. In Rwanda in the late eighties climbing beans from CIAT became a great success. Again, an intensive screening and seed distribution program would be necessary over a period of 4-5 years in order to introduce such an innovation successfully.

Two **other food crops** deserve increased attention: irish potatoes and wheat. Johannson (1988) in his case study on the village Longoi found that **irish potatoes** - being a valuable cash crop - can produce the highest return under rainfed production. It can be concluded that the area under irish potatoes increased within the last 15 years, although no respective data have been assessed.

In Mtae as well as in Mlao division quite a number of farmers - asked for crop alternatives - consider **wheat** an interesting alternative to maize production in higher altitudes. They consider the yield of wheat in years if "normal" rainfall as good as with maize and better in years with unreliable or low rainfall. Also for Wheat it can be concluded that the acreage under this crop has extended moderately. Appropriate seed is available in the district and can be bought from Shell-Craft in Lushoto. But there is no tradition in preparing food from wheat and this might be the main constraint for a significant extension of its cropping area.

Alternatives and options. Among the agronomic innovations discussed the most important ones for the intensification of cropping systems would be to introduce new varieties for maize (composites) and climbing beans. The identification, multiplication and distribution of improved varieties could increase considerably the productivity of land.

5.2 Fodderplants

Many fodderplants have been tested mainly with the goal to integrate them into the "macro contour line" (Pfeiffer 1990), but no data exist on the yield performance of fodderplants on farmers fields, on terraces or other places in the land scape.

An important **shrub** is *Calliandra callothyrsus*. It shows best performance under warm-dry conditions (Mlalo). Outstanding yields under 6-monthly cutting frequencies can be achieved. This is confirmed for Rwanda by Gahamanyi (1989), and Neumann & Pietrowicz (1985) found a dry matter yield of 7 t/ha+y leaf and 4.5 t/ha+y branches. Similar results were achieved with *Leucaena diversifolia* (Pfeiffer 1990), which also did well in the cold dry zone. Under dry warm conditions dry matter yields of 4-7 t/ha+y were obtained.

Among the **fodder grasses** Guatemala grass (Trypsacum laxum) the species propagated most by SECAP has been Guatemala grass (Trypsacum laxum). According to Pfeiffer (1990) it grows well in all agro-ecological zones and outyields all other species (9.7-26.9 t/ha+y). It is followed by Napier grass which is considered to be more drought tolerant, less suitable for the dry cold region and to have a higher stalk percentage than Guatemala grass.

However, the farmers in all regions have more or less abandoned Guatemala grass. As already mentioned above they consider it too competitive and too exhausting. Instead they favor Napier grass, which is cultivated to reinforce the terrace embankments. To a minor extent also Bana grass is cultivated, a cross bred of *Pennisetum purpureum* and *Pennisetum americanum.* This species performed best in the dry warm region.

Options and alternatives. Despite quite a number of possible improvements in the field of agronomy at present no recommendations for immediate action are given.

6. Recommendations for action of SECAP

Soil fertility maintenance is by far the most important aspect in the effort to intensify on a sustainable basis the cropping systems under rainfed agriculture, and there is quite number of technologies available that could successfully be applied. The production and application of manure, the introduction of green manuring, the intensifcation of agroforestry, and the strengthening of the crop - animal husbandry linkage, all little or no physical external input. But another kind of increased external input is urgently needed: Site specific technical knowledge and the farmers´ability to transform and incorporate this knowledge into practical methods, which are applied within his system of farming. In other words: agricultural extension and training should be intensified.

Recommendations for actions of SECAP have not only to consider possible options (as mentioned above) but also the potential of SECAP in terms of funds and the additional workload involved. Taking into account that over the last 9 years SECAP was not able to implement any trial or research activities it would be futile to recommend any new on-farm trial or other research activities. In view of the existing workload (soil and water conservation) it seems only realistic that a few aspects are included in the already existing extension activities in the divisions. Namely the techniques of producing and applying manure and compost and techniques on green manuring deserve more attention and could be incorporated into the existing work-schedules without big additional effort. Also it is proposed to elaborate and document a comprehensive set of technical recommendations.

6.1 Promotion of organic manures and composting

At present the support given to farmers concentrates too much on aspects of soil and water conservation. Farmers should be trained more intensively to improve their techniques in the production, collection and composting of organic manures. This concerns in first place the resources dung and urine from animals but also crop residues. Small incentives should be given to make this topic more important as it already is. One possibility could be to conduct a farmer competition on catchment level. The one who is applying the best compost production technology and who is applying best compost on bench terraces is rewarded the first price etc.

6.2 Propagation of Dolichos lablab

Green manuring is a promising technology that should be added to the already existing measures on soil fertility maintenance. In particular, it is recommended to promote Dolichos lablab. Dolichos is not unknown to the people, and it contains several benefits (food, animal feed and soil fertility). It should be planted as a relayed intercrop to maize in the regions with warm humid and warm dry climate. A vehicle for propagation could be to ask progressive farmers for seed multiplication and to use the multiplication plots as an on-farm demo field and may be even with a trial component. But the aim should be extension not research. It has also to be kept in mind that intercropping is not an easy innovation. Its propagation requires a certain intensity and endurance. One year testing will not be enough. Being a real innovation this extension message should be pursued at least over a period of three years.

6.3 Documention of existing knowledge and experience

It has often been deplored in this report that there is a lack of data. There is also a lack of documentation of existing knowledge. A lot of experience and knowledge are in the heads of district technical staff and SECAP employees and scattered over many project documents which are more or less inaccessible to the public. People are transferred to other places and normally do not pass all their knowledge to their predecessors, documents disappear and most of the knowledge will be lost, unless compiled an written down. Also, it is envisaged that SECAP may close down in the year 2000.

It is therefore of utmost importance for a 16 year old project like SECAP to thoroughly document all the knowledge and experience that have been gained over this period and thus make it available to others - extension workers as well as administrators. It is therefore recommended

a) to elaborate sound technical papers or small manuals on the existing production systems in the fields of field crops, vegetable production and animal husbandry, and to finalize the existing technical paper on soil and water conservation (SECAP/TIP 1995), and

b) to write a "state of the art report" on natural resources management and agricultural development on technologies and concepts that have been developed by SECAP in Lushoto district. This document should contain the development of presently practiced technologies such as agroforestry, soil and water conservation etc. and also the development of the presently practiced concepts in natural resources management such as the catchment approach, land use planning etc. The appendix in annex VI gives a draft outline of such a state of the art report.

Both activities cannot be accomplished by the SECAP staff alone.The SECAP team

Annex I Literature used

Agboola, A.A. and Fayemi, A.A.A. (1972b): Effect of soil management on corn yield and soil nutrients in the rain forest zone of Western Nigeria. Agronomy Journal 64 (5): 641-644.640 pp.

Agboola, A.A., and Fayemi A.A.A. (1972a): Fixation and excretion of nitrogen by tropical legumes. Agronomy Journal 64 (4): 409-412.

Buch, M.W. (1982/83): Semiquantative Beschreibung von Bodenerosionj (Rezente Abtragung und Akkumulation) an Hängen utnerschiedlicher Landnutzung, Neigung und Längge in fünf Dorgebieten der westlichen Usambara Mts. /Tansania. Teil I: Ergebnisse der Geländearbeit, Teil II: Ergebnisse und vergleichende standörtlich pedogenetische Ausdeutung der Laboruntersuchungen.

Crowder, LV. (1960): Gramineas y leguminosas forageras en Colombia. DIA Boletin Technico 8. Bogota.

Egger, K. J. Huljus, O. Pompl and D. Prinz (1980): Soil Erosion Control and Afforestation in the West Usambaras (Phase I). Feasibility Study. Göttingen, September 1980.

FAO (1979): Azolla propagation and small scale biogas technology. Rome. FAO Soils Bull. No. 41, 81 pp.

Feger, K.H. (1993): Bedeutung von ökosysteminternen Umsätzen und Nutzungseingriffen für den Stoffhaushalt von Waldlandschaften. Habilitationsschrift. Freiburger Bodenkundliche Abhandlungen. Institut für Bodenkunde und Waldernährungslehre. Albert Ludwigs Universität. Freiburg.

Geus, J.G.de (1973): Fertilizer Guide for the Tropics and Subtropics. Centre d´étude de l´azote. Zürich.

Pietrowicz P. and I. Neumann (1987): Fertilization et amelioration des sols. Etude sur l´application d´engrais vert, de la fumure organique et des engrais mineraux. PAP, Etudes et Experiences No. 11. Deutsche Fassung. Manuskript Nyabisindu.

Graaff, J.de (1993) Soil Conservation and sustainable land use. An economic approach. Royal Tropical Institute. Amsterdam

ISAR (1988): Rapport annuel 1987, publié en Avril 1988. Mimeo ISAR Rubona, Rwanda.

Iversen, S.T. (1991): The Usambara Mountains, NE Tanzania: History, Vegetation and Conservation. Uppsala.

Jaiswal, P.L., A.M. Wadhwani, M.K. Jain and N. Chhabra (Eds.) (1971): Handbook of manures and fertilizers. Indian Council of Agricultural Research, 2nd ed., New Delhi, 396 p.

Johannsson, L. (1988): The chambogo programme - an evaluation of the early implementation. A case study of attitudes to the forest at one sub-catchment; economic evaluation and cost-benefit analysis; general implementation problems. TIRDEP-SECAP. Lushoto, Tanzania.

Kaswamila, Abiud Luckius Wa (1995): Assessement of the effectiveness of certain soil conservation practices by soil surface microtopographic features. A case study of Mlesa, Mwangoi and Majulai in the West Usambara Mountains (Tansania). Msc Thesis ITC, Enschede, The Netherlands.

King, F.H. (1911): Farmers of Forty Centuries. Democart Printing Co. Madison Wisc. 441 pp.

Kotschi, J., I. Neumann, P. Pietrowicz, Jörg Haas (1991): Standortgerechte Landwirtschaft in Ruanda. Zehn Jahre Forschung und Entwicklung in Nyabisindu. Schriftenreihe der GTZ No. 223. GTZ. Eschborn.

Kwakye, P.K. (1980): The effects of the method of dung storage and its nutrient (NPK) content and crop yield in the north east savanna zone of Ghana. In: FAO (1980): 282-288.

Lindgren (1988): Machakos Report 1988.: Economic Evaluation of a Soil Conservation Projectin Machakos District, Kenya, Minsitry of Agriculture. Nairobi.

Ludwig, H.D. (1967): Ukara - Ein Sonderfall tropischer Bodennutzung im Raum des Victoria Sees. München, Institut für Wirtschaftsforschung Afrika-Studien Nr. 22, Weltforum-Verlag 251 pp.

Lundgren, L. (1993): Twenty years of soil conservation in Eastern Africa. Regional Soil Conservation Unit/SIDA, Nairobi.

McCalla, T.M. (1975): Use of animal wastes as a soil amendment. In FAO: Organic materials as fertilizers. FAO Soils Bulletin No 27. Food and Agriculture Organisation. Rome. 83-88.

Milne, G. (1937).: Essays in Applied Pedology. I: Soil Type and Sopil Mangement in Relation to Plantation Agriculture in East Usambara. The East African Agricultural Journal. P. 7-20.

Mugyabuso, Rwelengera (1986): Wheat measurement survey report Shume zone - Lushoto. September - October 1986.

Mukeni, P.N.S. (1992): Role of Soil Management in Enhancing Sustainability of Smallholder Cropping Systems in some Agro-ecosystems of Tanzania: A Review.

Müller-Sämann, K.M., J. Kotschi (1994): Sustaining Growth. Soil fertility management in tropical smallholdings. Weikersheim. 486 p.

Neel, H. (1974): L´amelioration des sols des régions d´altitude. Note technique 11. ISAR-Rubona, Rwanda.

Neumann, I. und P. Pietrowicz (1985): Agroforstwirtschaft in Nyabisindu - Untersuchungen zur Integration von Bäumen und Hecken in die Landwirtschaft. Projet Agro-Pastoral de Nyabisindu; Etudes et Experiences No.9. GTZ Eschborn.

Ofisi Ya Mkuu Wa Wilaya (1997): Taarifa Fupi ya maendeleo ya wilaya ya Lushoto Iliyonandaliwa Kwa ajili ya ziara ya rais wa jammuri wa Muungano wa Tanzania na mwenyenkiti wa CCM taifa M. Benjanin William Mkapa Tarene 19.2.-20.3.97.

Pfeiffer, R. (1990): Sustainable Agriculture in Practice - the Production Potential and the Environmental Effects of Macro-contourlines in the West Usambara Mountains of Tanzania. Dissertation. Inst. für Pflanzenbau und Grünland, Universität Hohenheim. Stuttgart.

Rodriguez, M.J. (1972): Algunos aspectos del cultivo del mais (Zea mays), Revista ICA/Kolumbien 7 (2): 89-110.

Sanchez P.A. & J.D. Salinas (1981): Low-input technology for managing oxisols and ultisols in tropical America. Adv. in Agron. 34: 279-406.

Sauerlandt, W. (1948): Grundlagen der Bodenfruchtbarkeit - Humusdüngung und Bodengare. Lüneburg, Kinau. 127 pp.

Schaafhausen, S. (1981): Bodenerosion in den West Usambaras/Tansania. Qualitative Untersuchungen zur Bodenerosion in fünf Dorfgebieten unterschiedlicher Landnutzung. Diplomarbeit im Fachbereich Geographie, Universität Hamburg. unveröffentlicht.

Scheffer & Schachtschabel (1982): Lehrbuch der Bodenkunde. Stuttgart.

Schnurr, J. (1984): Untersuchungen über den Einfluß der Baumarten Erythrina abyssinica, Grevillea robusta und Albizzia schimperiana auf den Bodenzustand und die unter ihrem Schirm wachsenden Maispflanzen in einem agroforstwirtschaftlichen System. Diplomarbeit Universität Göttingen.

SECAP/TIP (1995): Technical recommendations for soil and water conservation measures and agroforesty, jointly developed by SECAP and TIP. Part 1 Biological and Physical Soil and Water Conservation Measures. SECAP/TIP Lushoto, May 1995.

SECAP (1994): Initial Farmer Interviews. Project file. SECAP, Lushoto.

SECAP (1994): Initial Farmer Interviews in the Villages of Malindi, Mlesa and Shashui. July 1994, SECAP Project File, unpublished.

Shenkalwa, E. M. (1989): Evaluation of erosion control in Tanzania by soil physico-chemical analysis. Msc. Thesis. International Training Centre for Post Graduate Soil Scientists. State University of Gent.

Skerman P.J. (1977): Tropical Forage Legumes. FAO Rome. 609 pp.

Taube (1991): Wirtschaftliche Aspekte des Erosionsschutzes, SECAP Lushoto Mai 1991.

Taube, G. (1988): An economic analysis of SECAPs basic recommendations for soil erosion control. TIRDEP-SECAP. Lushoto.

Webster and Wilson (1980): Agriculture in the Tropics. Second edition. Longman. London.

Werner, J. (1995): Consultancy Report of the SECAP Trial Programme. SECAP Lushoto, April 1995.

Woyteck, R. (1986): Abschlußbericht. Soil Erosion Control und Agroforestry Project Lushoto (SECAP). TIRDEP-SECAP. Lushoto.

Annex II: **Agricultural statistics Lushoto District**

		maize			beans	
year	t	ha	t/ha	t	ha	t/ha
77/78	50000	40000	1,25	20000	15000	1,33
84/85	31488	52360	0,60	28243	29268	0,97
85/86	67982	48167	1,41	29966	29966	1,00
86/87	26108	22699	1,15	26057	24828	1,05
87/88	20670	17135	1,21	36675	35575	1,03
88/89	20453	17044	1,20	27340	13251	2,06
89/90	19771	16117	1,23	12398	6189	2,00
90/91	16900	14084	1,20	33766	16883	2,00
91/92	15955	12618	1,26	33766	16656	2,03
92/93	9272	11046	0,84	15125	12604	1,20
93/94	15300	12830	1,19	9784	4892	2,00
94/95	19066	15830	1,20	34706	17159	2,02
95/96	9302	13278	0,70	8083	15944	0,51
x	24789	22554	1,11	24.300	18324	1,48

Source: Files from DEO/Lushoto

Annex III Costs of soil and water conservation

III/1. Simplified calculation of costs on soil and water conservation - *Fanya juu*

Assumptions:

field size:	1 ha	slope:	24%	length of each terrace:	100 m
field length:	100 m	VI:	1.4m	No. of terraces:	16
		spacing:	6.0m	total length of terraces/ha	1600m

Inputs	Costs per hectare[3]						
		Establishment costs			Maintenance costs		
	Units	No. Units	Tsh/unit	Tsh total	No. Units	Tsh/unit	Tsh/total
Labour							
a) Fany Juu	Pers. days	100	500	50.000	30	500	15.000
b) Cut off drain	m	100	150	15.000	100	30	3.000
c) Grass strips	Pers. days	20	500	10.000	4	500	2.000
Equipment							
Hoes, shovels, axes	tools	3	2500	7.500			
Materials							
a) grass splits[1]	m^3	4	800	3.200	2	800	1.600
b) seedlings[2]	seed-lings	80	10	800	8	10	80
Total							

Calculation based on prices of 1995.

1) 1 m3 for 400 m of single row

2) 1 seedling every 10 m every 2nd terrace

3) Only incremental costs directly related to the technique, i.e. excluding costs the farmer would have had anyway. Additional costs of manuring/fertilizing are still to be considered.

Reduction of cultivable area:	1 ha
Area coverd by one fanya juu:	600 m2 (6,0 HI x 100 m length)
max bench are of one fanya juu:	580 m2 (5,8 HI x 100 m length)
cultivable bench area of on fanya juu:	?
total cultivable are after terracing:	0,80 ha ?

III.2: Simplified calculation of costs of soil and water conservation - example bench terraces (draft) - (T. Münzel, SECAP Lushoto 1995)

Assumptions:					
field size:	1 ha	slope:	40 %	length of each terrace:	100 m
field length:	100 m	VI:	1.4 m	no. of terraces:	26
field width:	100 m	spacing:	3.8 m	total length of terraces/ha:	2600 m

Inputs	Unit	Costs per hectare 1)					
		Establishment costs			Maintenance costs (annu		
		no. units	TSh/unit	TSh total	no. units	TSh/unit	TSh
Labour:							
a) Terraces	pers. days	200	500	**100000**	40	500	2(
b) Cut off drain	m	100	150	**15000**	100	30	:
c) Grass strips	pers. days	20	500	**10000**	4	500	:
Equipment:							
Hoes, shovels, pick axes (12 pieces for 4 ha)	tools	3	2500	**7500**			
Materials:							
a) grass splits (1 m3 for 200 m of double row)	m3	13	800	**10400**	2	800	
b) seedlings (1 seedling every 10 m every 2nd terrace)	seedlings	130	10	**1300**	13	10	
TOTAL				**144200**			2

1) Only incremental costs directly related to the technique, i.e. excluding costs the farmer would have had an
Additional costs of manuring/fertilizing still to be considered.

Reduction of cultivable area:		
tot. cultivable area before terracing:	1 ha	
area covered by one terrace:	380 m2	(= 3.8 m spacing x 100 m length)
max. bench area of one terrace:	350 m2	(= 3.5 m HI x 100 m length)
cultivable bench area of one terrace:	280 m2	(= 2.8 m width x 100 m length)
tot. cultivable area after terracing:	0.80 ha	
reduction of cultivable area:	20 %	

III.3: Calculation of production costs of raising tree seedling in a central nursery during 1 year

D R A F T (calculation for discussion purpose only)

No. of seedlings raised/year: 200000	Unit	No. of units per 100000	No. of units per 200000	TSh/unit	TSh total	Remarks/assumptions: (production costs to nursery gate)
						---> 2 seasons = 100000 per season
Variable costs:						
a) Use of inputs (variable)						
Seeds	kg	147.78	295.568	684	202274	---> see calculation Annex 1
Fertilizer (NPK 20/10/10)	bag	2	4	8000	32000	
Farm yard manure	lorry	4.25	8.5	10000	85000	
Polythene tube 4"	kg	157	314	800	251200	---> 1 kg = 700 pieces, 10% added for losses
Soil	lorry	17	34	-	0	---> ~ 10 m3 per lorry for ~ 6000 seedlings
Sand	lorry	1	2	2000	4000	---> ~ 10 m3 per lorry
b) Costs of capital for current assets						
Average value of inputs: 50% of total value)					*287237*	---> current assets
Interest value (opportunity costs of capital) 20%					57447.4	
c) Transport costs (without labour)						
Farm yard manure transport	km	297.5	595	300	178500	---> return trip 70 km
Soil transport	km	85	170	300	51000	---> return trip 5 km
Sand transport	km	24	48	300	14400	---> return trip 24 km
d) Labour costs						
Casual labourers outside nursery (e.g. transport)	person day	148	296	500	148000	
Drivers	person day	5	10	800	8000	
Casual labourers in nursery	person day	1155	2310	500	1155000	
Supervision in nursery	pers. month	12	24	15000	360000	
TOTAL VARIABLE COSTS					2546822	
Fixed costs:						---> Fixed costs are valid between 100000 and 200000 seedlings raised per year
a) Use of fixed assets						
Tools/Materials — Lifespan						
Hose pipes 3/4 " — 2 yrs.	30 m	2	2	13000	13000	
Watering cans — 3 yrs.	piece	4	4	3600	4800	
Pruning knives — 2 yrs.	piece	8	8	400	1600	
Sieves — 3 yrs.	m	8	8	2000	5333	
Wheelbarrow — 3 yrs.	piece	2	2	25000	16667	
Drums — 2 yrs.	piece	3	3	4000	6000	
Shovels — 2 yrs.	piece	4	4	1700	3400	
Buckets — 2 yrs.	piece	4	4	2000	4000	
Hoes — 2 yrs.	piece	4	4	1500	3000	
Pangas/bush knives — 2 yrs.	piece	2	2	800	800	
Buildings						
Working shed — 10 yrs.	shed	1	1	150000	15000	
Store — 10 yrs.	store	1	1	200000	20000	
Latrine — 5 yrs.	latrine	1	1	50000	10000	
b) Costs of capital for fixed assets						
Average value of fixed assets: 50% of total value)					*172000*	
Interest value (opportunity costs of capital) 20%					34400	
c) Costs of maintenance and repair						
Tools/Materials 10% of purchasing value					14400	
Buildings 10% of establishment costs					40000	
TOTAL FIXED COSTS					192400	
TOTAL COSTS PER YEAR					2739222	
TOTAL COSTS PER SEEDLING					**13.7**	
Labour requirements:						
Sand, soil, manure transport (driver)	person day	5	10	800	8000	
Sand, soil, manure transport (casuals)	person day	10	20	500	10000	
Soil digging, loading	person day	130	260	500	130000	
Manure collection and loading	person day	8	16	500	8000	
Manure, soil sieving/mixing	person day	65	130	500	65000	
Pot filling	person day	250	500	500	250000	
Root Pruning	person day	120	240	500	120000	
Tending operation	person day	720	1440	500	720000	
Supervision	month	12	24	15000	360000	
T O T A L		1320	2640	-	1671000	

SECAP Lushoto, June 1994

III.4: Calculation of production costs of raising tree seedling in a private nursery during 1 year (SECAP Lushoto June 1994)

DRAFT (calculation for discussion purpose only)

No. of seedlings raised/year: 20000	Unit	No. of units per 10000	20000	TSh/unit	TSh total	Remarks/assumptions: (production costs to nursery gate)
						--->2 seasons = 10000 per season
Variable costs:						
a) Use of inputs (variable)						
Seeds	kg	14.80	29.6	684	20246	--->see calculation Annex 1
Fertilizer (NPK 20/10/10)	tin	1.2	2.4	1330	3192	
Farm yard manure	tin	30	60	10	600	
Polythene tube 4"	kg	15.7	31.4	800	25120	---> 700 pieces/kg, 10% added for los
Soil	m3	17	34	-	0	---> ~ 10 m3 for 6000 seedlings
Sand	m3	1	2	200	400	
b) Costs of capital for current assets						
Average value of inputs: 50% of total value)					*24779*	--->current assets
Interest value (opportunity costs of capital) 20%					4956	
c) Transport costs						
Labour costs only, see below						
d) Labour costs	person day	131	262	500	131000	
see detailed calculation below						
TOTAL VARIABLE COSTS					185514	
Fixed costs:						--->Fixed costs are valid between 10000 and 20000 seedlings raised per year
a) Use of fixed assets						
Tools/Materials — Lifespan						
Watering cans — 3 yrs.	piece	1	1	3600	1200	
Pruning knives — 2 yrs.	piece	2	2	400	400	
Drums — 2 yrs.	piece	1	1	4000	2000	
Shovels — 2 yrs.	piece	1	1	1700	850	
Buckets — 2 yrs.	piece	2	2	2000	2000	
Hoes — 2 yrs.	piece	1	1	1500	750	
b) Costs of capital for fixed assets						
Average value of fixed assets: 50% of total value)					*7800*	
Interest value (opportunity costs of capital) 20%					1560	
c) Costs of maintenance and repair						
Tools/Materials 10% of purchasing value					1560	
TOTAL FIXED COSTS					10320	
TOTAL COSTS PER YEAR					195834	
TOTAL COSTS PER SEEDLING					**9.8**	
Labour requirements:						
Soil collection	person day	4	8	500	4000	
Manure collection	person day	1	2	500	1000	
Site preparation	person day	3	6	500	3000	
Seed bed preparation	person day	2	4	500	2000	
Sowing	person day	1	2	500	1000	
Soil/manure mixing	person day	2	4	500	2000	
Pot filling	person day	34	68	500	34000	
Root Pruning	person day	12	24	500	12000	
Tending operation	person day	72	144	500	72000	
TOTAL		131	262	500	131000	

SECAP Lushoto, June 1994

III.5 Calculation of production costs of grass multiplication (draft) (SECAP/ELCT Irente Farm Lushoto, June 1995)

sumptions:

Calculation is done for Napier which is the preferred species in many villages.
The cuttings are harvested two times per year (i.e. 2 cuts per year).
One cutting requires three nodes (i.e. a stem with 6 nodes yields 2 cuttings).

Size of multiplication plot:	1	ha	(pure stand)		
Spacing:	0.5	x	0.5	m	
Plants per ha:	40000	-	10%	losses =	**36000**

No. of productive stems/plant 1 year after establishment:		3.3	
Thereafter:			
No. of productive stems/plant 6 months after last cut:		3.3	
No. of productive stems/plant per year (2 cuts):		6.6	
No. of cuttings/stem after 6 months:	- good site:	1.6	(fast growing, long internodes, little lignification)
	- poor site:	3.9	(slow growing, short internodes, more lignification, more resistant)
No. of cuttings/ha after 1st year:	- good site:	152064	20% losses already deducted
	- poor site:	370656	
No. of cuttings/ha per year thereafter:	- good site:	304128	
	- poor site:	741312	

al costs per ha:

		pers.days per season	seasons per year	pers.days per year	TSh per pers. day	TSh total
abour	Land preparation (every 5 yrs.)	70	-	14	500	7000
	Planting (every 5 yrs.)	100	-	20	500	10000
	Weeding	64	2	128	500	64000
	Slashing	30	2	60	500	30000
	Harvesting	120	2	240	500	120000
	Gap filling	80	2	160	500	80000
	Fertilizing/manuring	40	2	80	500	40000
	Total					351000
nputs	Farm yard manure/fertilizer					100000
	Total costs per ha per year					**451000 TSh**

ts per 1 m3 of cuttings:

Assumption: 1 m3 of Napier cuttings can plant 400 m of a single contour line at a spacing of 0.3 m

I.e. 1 m3 of Napier cuttings equals 1333 cuttings

		good site	poor site
cuttings per ha	year 1:	152064	370656
	years 2-5:	304128	741312
	avg./year:	273715	667181
m3 per ha	**avg./year:**	**205**	**500**
Costs per 1 m3 of cuttings:		**2197**	**901 TSh**

Costs do not include loading and transport to the site

SECAP Lushoto

1995

Labour inputs for physical SWCM - examples

(DRAFT - for internal discussion only)

Bench terrace

Site	Calculation	hrs/m	m/hr	m/md	hrs/ha	md/ha	TSh/md	TSh/ha
Kwemashai, primary school plot, pupils S%: 35-45 Vl (m): 1.3 Spacing (m): 3.5	100 pupils x 2 hrs = 200 hrs for 5 terraces x 50 m length = 250 m length	0.8	1.3	**10.0**	2286	**286**	500	142857
Kwemashai, primary school plot, pupils S%: 35-45 Vl (m): 1.3 Spacing (m): 3.5	90 pupils x 4.5 hrs = 405 hrs for 18 terraces x 60 m length = 1080 m length	0.375	2.7	**21.3**	1071	**134**	500	66964
Kisangara, private plot, Kiwili group S%: 35-40 Vl (m): 1.4 Spacing (m): 3.9	8 women x 5 hrs = 40 hrs for 5 terraces x 14 m length = 70 m length	0.571	1.8	**14.0**	1465	**183**	500	91575
Kivumo, private plot, Kiwili group S%: 35-40 Vl (m): 1.3 Spacing (m): 3.7	10 men x 6 hrs = 60 hrs for 9 terraces x 15 m length = 135 m length	0.444	2.3	**18.0**	1201	**150**	500	75075
Mambo, private plot, casual labour S%: 35 Vl (m): 1.2 Spacing (m): 3.4	12 men x 24 hrs = 288 hrs for terraces x m length = 1065 m length	0.27	3.7	**29.6**	795	**99**	500	49710
Mambo, private plot, family labour S%: ´30 Vl (m): 1.2 Spacing (m): 4.2	4 m./w. x 6 d. = 24 d. for 10 terraces x 30 m length = 300 m length	0.64	1.6	**12.5**	1524	**190**	500	95238

Fanja juu

Site	Calculation	hrs/m	m/hr	m/md	hrs/ha	md/ha	TSh/md	TSh/ha
Kingweiwei, private plot, Kiwili group S%: 45 Vl (m): 1.5 Spacing (m): 3.7	10 m./w. x 6 hrs = 60 hrs for 11 fanja juus x 25 m length = 275 m length	0.218	4.6	**36.7**	590	**74**	500	36855

Cut-off drain

Site	Calculation	hrs/m	m/hr	m/md
Mlesa-Mtae, private plot, contract labour S%: 55	3 men x 16 hrs = 48 hrs for 1 cut-off x 55 m length = 55 m length	0.873	1.1	**9.2**
	money paid for contract = TSh 5000 / 55m =			**91** TSh/m
Mambo, private plot, contract labour S%: 45	4 men x 8 hrs = 32 hrs for 1 cut-off x 40 m length = 40 m length	0.8	1.3	**10.0**
	money paid for contract = TSh 6000 / 40m =			**150** TSh/m

Annex IV Research findings on soil fertility maintenance by manure, compost, green-manuring and agroforestry

IV.1 Dung and urine production of different agricultural livestock (rough estimates)

	Jaiswal et al. (1971)		Sauerlandt (1948)		Estimated amount per TLU*	
	Dung	Urine	Dung	Urine	Dung	Urine
Animal species	------------ kg or liters/day (fresh matter) ------------					
Milk cow	23.5	9.0	20-25	12	11	6.5
Horse	16.0	3.6	10-15	5	5-7	2.5
Pig	2.7	1.5	1.5-2.5	1.5	-	-
Sheep/Goat	1.1	0.6	1.0-1.5	1.0	-	-
Chicken	0.04	-	-	-	-	-

* A Tropical Livestock Unit (TLU) is a head of cattle with a live weight of 250 kg. Estimated values are given in this measurement rather than in the German "heavy livestock unit" (*Großvieheinheit*, GVE) of 500 kg live weight)

IV.2 Composition of fresh dung from several species of livestock

Animal	K_2O %	CaO %	C/N ratio
Cattle	0.15 (0.14-0.18)	0.2 (0.1-0.3)	20-25
Horse	0.3	0.2 (0.17-0.25)	24
Sheep/Goat	0.25 (-0.29)	0.4 (-0.46)	20-25
Pig	0.4	0.07 (0.05-0.09)	19-20
Chicken	0.8 (0.6-2)	4.0 (2-6)	9-11
Duck	0.6 -	1.7 -	-
Rabbit	2.7 -	0.1 -	-
Water buffalo	0.17	0.4	25-28

Sources: Sauerlandt (1948); Jaiswal et al. (1971) and McCalla (1975)

IV.3 Average urine composition of some species of livestock

Animal	Water (%)	Org. matter (%)	N (%)	P_2O_5 (%)	K_2O (%)	CaO (%)
Cow	92.6 (92.5)	4.8 (3.0)	1.21 (1.0)	0.01 (0.1)	1.35 (1.5)	1.35 (0.3)
Horse	89.6 (89.0)	8.0 (7.0)	1.29 (1.2)	0.01 (0.05)	1.39 (1.5)	0.45 (0.15)
Sheep	86.3 (87.5)	9.3 (8.0)	1.47 (1.5)	0.05 (0.10)	1.96 (1.8)	0.16 (0.3)
Goat	- -	- -	- (1.9)	- (0.12)	- (0.59)	- (0.16)
Water buffalo	81.0	-	0.6	traces	1.61	traces
Pig	96.6 (94.0)	1.5 (2.5)	0.38 (0.5)	0.10 (0.05)	0.99 (1.0)	0.0 (0.02)

Source: Sauerlandt (1948) and Jaiswal et al. (1971)
(Data from Sauerlandt in parentheses)

IV.4 Effect of different methods of storing cow dung in Ghana on N-, P- and K-contents after 3 months of storage.*

Type of storage**	Dry matter (%)	Nitrogen (%)	Phosphate (%)	K_2O (%)
a) Loose pile (without cover)	22 (-28)	0.71 (-59)	0.50 (-28)	1.32 (-45)
b) Stacked and immediately compressed (covered)***	26 (-16)	0.93 (-47)	0.51 (-27)	1.51 (-37)
c) Loosely stacked, compressed after 3 days (covered)***	24 (-22)	0.79 (-55)	0.55 (-20)	1.45 (-40)
d) Stored in a pit (covered)***	27 (-12)	1.48 (-15)	0.60 (-12)	2.14 (-11)

* The values in parentheses express the relative losses compared with the original material; ** Stack height in meters; *** Covering comprises a layer of earth and grass.

Source: Kwakye (1980)

IV.5 Maize yields under continuous maize cultivation and under rotation with green manure (1928 to 1950)

System	Number of maize harvests	Total maize yields (bags/acre)	Annual average (bags/acre)
Continuous maize	22	132.2	6.0
Maize rotated with green manure	14	186.9	13.5

Site: 1650 m a.s.l.; rainfall 750 mm/yr (monomodal)

Source: Rattray and Ellis, cited in Webster and Wilson (1980)

IV.6 The influence of nitrogen, weed fallow and crop rotation on maize yields (t/ha) in Colombia (1956 to 1964)*

Nitrogen (kg/ha)	Continuous maize crop	Maize/weed fallow	Maize/ Soybean	Maize/ Dolichos
Long rainy season				
0	2.95	3.69	3.28	5.91
40	4.52	4.68	4.73	6.20
80	5.52	5.66	5.38	6.23
Short rainy season				
0	2.06	----	2.96	4.86
40	2.91	----	3.51	4.85
80	3.51	----	4.45	4.84

* Averaged over 9 years

Source: Rodriguez (1972)

IV.7 Influence of undersown legumes on maize yields (kg/ha) during the first growing period in humid western Nigeria

Mineral fertilizer (kg/ha)	No legumes	*Vigna unguiculata*	*Phaseolus aureus*	*Calopogonium mucunoides*
-	1790 c*	1850 bc	3080 a	1850 bc
45	3080 a	2750 ab	3070 a	3050 a
90	3420 a	2750 ab	2750 ab	3070 a
135	2580 b	2920 ab	1960 bc	2920 ab

* Values with the same letters do not differ significantly (p = 0.05)

Source: Agboola and Fayemi (1972b)

IV.8 Influence of unfertilized undersown legumes* on maize yields (kg/ha) during the second growing period in humid western Nigeria

--- Legume undersown in preceding maize crop ---			
None	*Vigna unguiculata*	*Phaseolus aureus*	*Calopogonium mucunoides*
1210	1970	1510	2120

* Incorporated as green manure: although the maize residues were incorporated with the green manure shortly before the second sowing, there was no decrease in yields on the site.

Source: Agboola and Fayemi (1972b)

IV.9 Effect of different maize cultivation techniques on grain yield (kg/ha), on a ferruginous soil at Ibadan, Nigeria, 1966-67

Crop season	Without legumes	*Vigna unguiculata*	*Calopogonium muconoides*	*Phaseolus aureus*
1st season 1966	2520 a*	2670 a	2690 a	2800 a
2nd season 1966	1190 b	1150 b	2000 a	1150 b
1st season 1967	1610 b	2390 a	2560 a	2550 a
2nd season 1967	710 b	1270 a	1270 a	1230 ab
Average	1510 b	1870 ab	2240 a	1930 ab

* Values with the same letter do not differ significantly ($p = 0.05$)

Source: Agboola and Fayemi (1972a)

IV.10 Nutrient compostion of different fodderplants in Lushoto district

Species	N	P	K	Ca
Tripsacum laxum	1.71	0.07	1.73	0.26
Leucaena leucocephala	4.32	0.10	2.13	1.14
Desmodium intortum	2.99	0.10	2.78	1.18

Source: calculated from Pfeiffer (1990)

IV.11 Nutrient content of leave litter fall of Grevillea robusta (% dry matter)

	N	P	K	Ca	Mg
Grevillea robusta leaves	3.18	0.097	1.74	3.45	0.345
Source: Neumann and Pietrowicz (1985)					

IV.12 Nutrient content of in leaves of three commonly raised trees in Lushoto District (% dry matter)

	N	P	K	Ca	Mg
Grevillea robusta	1.0	0.06	0.25	1.7	0.42
Albizzia schimperiana	3.0	0.11	0.7	1.4	0.6
Erythrina abyssinica	3.8	0.38	3.1	1.4	0.36
Source: data compiled from Schnurr (1984)					

IV.13 Performance of Grevillea robusta in an agroforestry system in Rwanda

Cropping cycle	harvest after 6 years 420 trees/ha	harvest after 9 years 360 trees/ha
leaf (kg/ha)	2,380	4,400
branches (kg/ha)	4,760	8,800
timber m^3/ha	4.2	9.0
labour input (h/year)	89	103
Source: Preissler & Bennet (1987), extrapolated from Neumann & Pietrowicz (1985).		

IV.14 The effect of agroforestry on the performance of a cropping system in Rwanda

Treatment	without trees	250 trees/ha	yield surplus %
maize (kg/ha)	1,204	1,328	20
phaseolus beans (kg/ha)	798	797	--
soybeans (kg/ha)	312	220	-30
sweet potatoes (kg/ha)	2,439	3,038	25
timber (m3/ha)	---	5,9	---
branches (kg/ha)	---	4,800	---
Grevillea leaf (kg/ha)	---	2,100	---

Site: Nyabisindu, Rwanda

Assumption: for the trees along contours a 10% loss of cropping area is calculated. Accordingly the yields of field crops under trees had to be multiplied by the factor of 0.9.

Source: Kotschi (1987), adapted from Neumann and Pietrowicz 1985.

Lablab spp.

Lablab purpureus (L) Sweet (See Colour plates XXIV)

Synonym. Dolichos lab-lab.

Common names. Rongai dolichos, lab-lab bean (Australia), poor man's bean, Tonga bean (English), lubia (the Sudan), batao (Philippines), hyacinth bean (Brazil), frijol jacinto (Colombia), quiquaqua, caroata chwata (Venezuela), poroto de Egipto (Argentina), dolique lab-lab, dolique d'Egypte (French), fiwi bean (Zambia), chicarros, frijol caballo (Puerto Rico), gallinita (Mexico), frijol de adorno (El Salvador), wal (India).

Description. Summer-growing, rampant and vigorously twining herbaceous annual or short-lived perennial. Stems robust, 3 to 6 m, leaves trifoliate; leaflets broad ovate-rhomboid, 7.5 to 15 cm long, thin, acute at apex, almost smooth above and shortly hairy underneath. Petioles long and slender. Inflorescence lax, fascicled, of many-flowered racemes on elongated peduncles. Flowers white (in Rongai) or blue or purple, on short pedicels. Pod 4 to 5 cm long, broadly scimitar shaped, smooth and beaked by the persistent style, containing 2 to 4 seeds. Seeds in Rongai buff or pale brown coloured, ovoid, laterally compressed, with a linear white conspicuous hilum, 1.0 cm long × 0.7 cm broad (Barnard, 1967).

Distribution. Widespread throughout the tropics, especially in Africa as a food crop.

Season of growth. A summer-growing annual, biennial, or short-term perennial.

Temperature for growth. Requires warm temperatures for good growth. Does not grow rapidly till December in southeast Queensland, when temperatures exceed 29°C (84°F). It shoots rapidly in the spring from old plants. Minimum temperature for growth is about 3°C (37°F) (Murtagh and Dougherty, 1968). It is more tolerant of cold than velvet bean (*Mucuna pruriens*). Its frost tolerance is low. It usually seeds late and so early frosts affect it. In Georgia, United States, and Queensland, (Downes, 1966), a breeding programme for earliness of flowering and seed production is in progress.

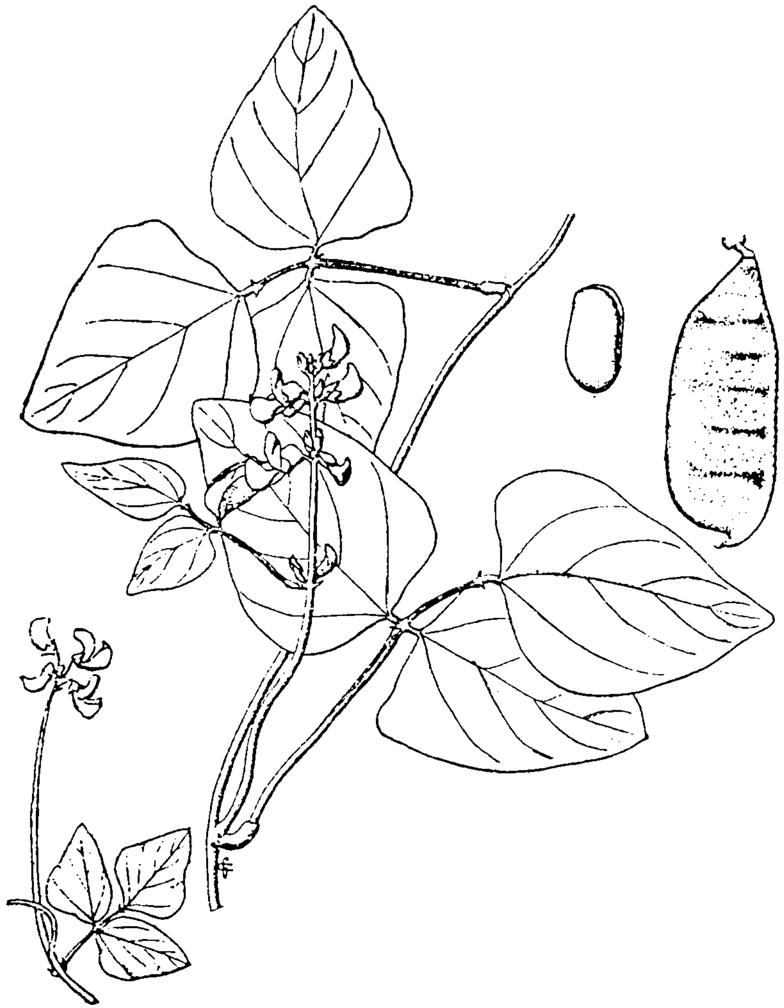

FIGURE 50. — *Lablab purpureus*

Left to right: flowering stem (× 0.5); growth habit; seed (× 0.5); pod (× 0.5) (Burkart, 1952).

Value as standover or deferred feed. Excellent if there are no frosts. It flowers late and carries a large body of feed into the winter. Even if frosted, if it has set seed the pods do not dehisce and so there is good feeding value in them alone. In Brazil the lablab crop planted with maize is fed off with the old maize residues after the maize harvest.

Feeding value. It is excellent for bridging the gap between summer and winter grazing crops and pastures (Luck, 1965b).

(*a*) *Chemical analyses.* French (1937) reported 11.74 percent crude protein, 37.67 percent crude fibre and 39.47 percent carbohydrates with 2 percent CaO, 0.42 percent P_2O_5, 0.36 percent Na_2O, 1.69 percent K_2O and 0.13 percent Cl in Lablab hay at Mpwapwa, Tanzania. Some of the leaf had been lost in making the hay. Luck (1965b) reported 25 to 26 percent crude protein in the leaf of Lablab cv Rongai compared with 18 to 23 percent for velvet bean, and the stem crude protein was 9 to 11 percent. Neme (1970, unpublished) recorded 22.17 percent crude protein and 27.44 percent crude fibre on a dry weight basis. Thurbon, Byford and Winks (1970) found Lablab hay to have a protein content of 11 to 14 percent. For weaner calves, it can be cut within 10 weeks to give a higher protein; for mature animals it can be cut later. Digestibility of the dry matter of the young plants (77 days) was 61.3 percent and for old plants (140 days) 48.6 percent, and for crude protein 66.4 and 61.7 percent respectively. Morris and Levitt (1968) reported 24.9 percent dry matter, 2.3 percent nitrogen, 30.1 percent crude fibre, 42.6 percent carbohydrates, 1.5 percent Ca, 0.3 percent P and 4.6 percent sugar in green Lablab before ensiling. In the resulting silage made from nonwilted and wilted material plus molasses, there was no significant difference in composition. The average dry matter was 38.2 percent, nitrogen 2.4 percent, crude fibre 30.9 percent, carbohydrates 37.9 percent, Ca 1.8 percent, P 0.3 percent and sugar 1.0 percent with final pH ranging from 4.2 to 4.6.

(*b*) *Digestibility.* Of the organic matter in the silage, digestibility was 49.1 percent (nitrogen 58.4 percent, crude fibre 55.3 percent and nitrogen-free extract 9.2 percent) for cattle. With sheep, digestibility figures were higher. The voluntary intake of sorghum/lablab silage was directly related to the proportion of lablab in the silage.

(*c*) *Palatability.* Green lablab is not usually eaten for up to four days (Murtagh and Dougherty, 1968), when the cattle become used to it and then eat it readily. The palatability of the hay (French, 1937) and silage (Ryley, 1966) for sheep has been recorded. Sheep ate the silage readily at approximately 1 kg/head/day.

Toxicity. A sole ration of lablab caused a "feedy" flavour in milk, similar to that from clovers and lucerne. Pasteurization and/or homogenization rendered milk acceptable (Hamilton, Fraser and Armitt, 1969). A case of bloat in cattle eating a sole diet of lablab was reported by Hymilton and Ruth (1968)

Seed harvesting methods. Often hand-picked in the tropics. It can be directly headed when the seed is ripe and standing or twining fine-stemmed crops, or it can be mown, cured in the field, and subsequently threshed.

Seed yield. Up to 1 000 kg/ha in Brazil and Bolivia. Davies and Hutton (1970) give an average figure of 500 kg/ha. Its seed yield is best at elevations of 1 200 to 1 800 m in Colombia. It does not seed very well in Venezuela.

Seed supplies. Most tropical countries have supplies of *Lablab purpureus* seed. Cv Rongai seed can be obtained from 5-16, 68, 80, 105 and 129.

Minimum germination and quality for commercial sale. Minimum germination of 75 percent, with a maximum of 10 percent hard seed and purity of at least 97.5 percent in Queensland, Australia. The seed is germinated under cover at 25°C (77°F) (Prodonoff, 1968).

Cultivars. Cultivar Rongai originally came from kenya as CPI 16883. A much earlier-flowering cultivar, cv Highworth, was introduced to Australia as CPI 20212 from southern India. It has high seed yield coupled with adequate foliage DM production. It has purple flowers and black seeds (Rongai's are white, and light brown).

There are numerous cultivars in the tropics. Selection No. 697 performs well in Brazil.

Diseases. The plant is attacked by numerous diseases throughout the world. In Australia, the Rongai cultivar is fairly disease-free. A stem rot caused by *Sclerotinia sclerotiorum* may attack the plant under wet conditions (Wilson and Murtagh, 1962).

Pests. Colbran (1963) found that the roots of *Lablab purpureus* were attacked by the nematodes *Helicotylenchus dihystera*, *Meloidogyne hapla* and *M. incognita*. It is also attacked by leaf-eating insects.

Main attributes. Its late maturing habit allows it to grow well into the autumn to provide feed between the normal summer species and winter species (e.g., oats). Its large seed allows easy establishment. It provides a high yield of dry matter and is drought tolerant. It is a good pioneer crop for improving land previously infested with *Axonopus* and *Cynodon* grasses ready for sowing grass/legume mixtures (Cassidy, 1968).

a little slower growing than cowpeas early in the season. It is easy to establish because of the large seeds. Murtagh and Dougherty (1968) showed leaf yield increasing rapidly in mid-summer and continuing up to the first frost (mid-June), whereas stem growth continued into the spring despite the frosted leaves. With a dense growth, the lower leaves are shed. These are lost to grazing, but form an excellent mulch and provide nitrogen on decomposition. Wilson and Murtagh (1962) in indicating growth rhythm of dolichos, cowpea and velvet bean in northern New South Wales, Australia, clearly show that the lablab retains its foliage and therefore its feed value, much later into the winter than the other two (see graph below):

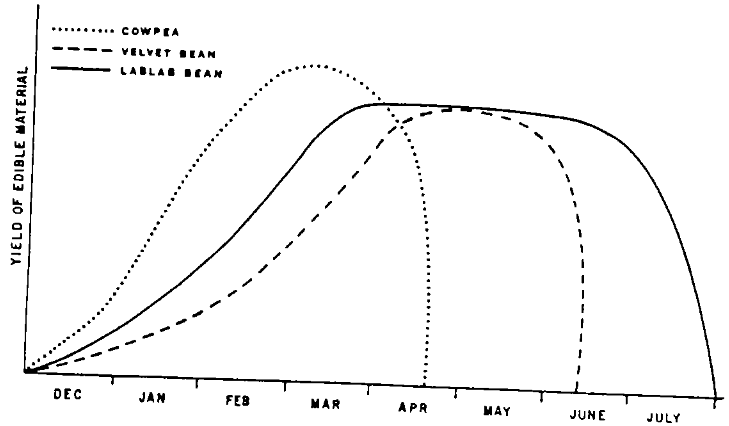

FIGURE 51. — Growth rhythm of legumes in New South Wales.

Nitrogen-fixing ability. In relation to yield. Besides nodulation from nitrogen fixation, it also supplies large amounts of nitrogen by leaf decay. At São Paulo, Brazil, it is estimated that it provides 220 kg/ha of nitrogen (Lambert, personal communication). Parbery (1967b) obtained dry matter yields up to 44 832 kg/ha in 287 days at the Kimberley Research Station, Australia, which contained 6 279 kg/ha of protein, unfertilized with nitrogen, indicating its extensive nitrogen-accumulating ability.

Response to defoliation. Will not stand heavy grazing of stems, but if only the leaf is taken it will provide two to three grazings in a season. Neme (1970, unpublished) advises that the plant should not be below 25 cm and recovery will take 4 to 5 months to give a second cut in Brazil.

Grazing management. Graze first in about 10 weeks from sowing to remove the leaf only and then remove the animals to allow further leaf to develop (Hamilton, 1969). Do not turn hungry animals onto a sole diet of lablab or bloat may occur, especially with young regrowth. Use a mixed grass/legume diet if possible or spray the material before grazing with an antibloat agent.

Response to fire. It will not tolerate fire.

Breeding system. The flowers are mainly cross-pollinated. Chromosome number 2n = 22. Patil (1958) has dealt with anthesis and pollination in the field.

Dry- and green-matter yields. Crowder (1960) reported 25 tons/ha of green material after 4 to 6 months' growth in Colombia. In Brazil, 40 tons/ha were obtained, and 35 tons of mixed maize and dolichos. van Rensburg (1967) obtained 5 438 kg DM/ha at Mount Makulu, Zambia, of 23.38 and 11.5 percent crude protein for the first and second cut, giving 870 kg of crude protein per hectare. In another experiment, 35.64 percent of the dry matter of a crop yielding 3 374 kg DM/ha was consumed at grazing. The dry matter of the whole crop consisted of 69 percent stem of 8.25 percent protein, and the leaf DM per hectare was 1 031 kg/ha containing 17.63 percent crude protein. Murtagh and Dougherty (1968) averaged a yield of 4 035 kg DM/ha from three sites on the north coast of New South Wales (lat. 28°50′S), leaf yield averaging 2 094 kg/ha. They felt that a ceiling leaf yield of 2 200 kg/ha can be expected in that environment. Neme (personal communication) calculated that one hectare of lablab could furnish 1 500 kg protein/ha.

Suitability for hay and silage. Lablab makes excellent hay if the leaf is preserved. The stem is difficult to dry and must be conditioned mechanically to hasten curing. Thurbon, Byford and Winks (1970) made hay of lablab in north Queensland, Australia. The material was mown, crushed (conditioned), windrowed and, when dry enough, then baled with a pick-up baler.

Ryley (1966) recorded good silage made from lablab alone in trench silos in Queensland. Skerman (1958b) made excellent silage with a mixture of lablab and sorghum, lifting the protein of the sorghum from 4.5 percent alone to 8.1 percent with a 1:2 lablab/sorghum mixture and to 11 percent with a 2:1 mixture. It is often grown with maize for ensiling. Morris and Levitt (1968) recorded the intake and digestibility of lablab silage. The material was ensiled immediately after harvesting, after wilting for two days with and without 3 percent molasses, and after wilting for three days. All silages were satisfactory and readily eaten by sheep.

Latitudinal limits. It extends south to beyond latitude 30°S. It is cultivated in Buenos Aires, Argentina (Burkart, 1952).

Altitude range. Sea level up to 2 000 m (Crowder, 1960), but it prefers the lower elevations.

Rainfall requirements. Used for a food crop in rainfalls as low as 400 mm with summer incidence and where deep soils are available. Prefers a rainfall in excess of 750 mm but not above 2 500 mm.

Drought tolerance. It is quite drought-tolerant when established (Luck, 1965b).

Tolerance to flooding. Very poor; it will not grow in wet soils (Luck 1965b; Wilson and Murtagh, 1962).

Soil requirements. Extremely tolerant of soil texture, growing in deep sands to heavy clays, provided drainage is good. It will grow in a wide range of pH, from 5.0 to 7.5. Salinity reduces the plant population and produces chlorotic leaves (Wilson, personal communication).

Rhizobium relationships. Lablab does not easily nodulate with native strains of rhizobia, and although it is often not inoculated it is preferable to treat the seed with the cowpea strain CB 756 (Norris, 1967). Diatloff (1967) recorded poor growth on poor sandy soils in southeast coastal Queensland, where uninoculated plants yielded 203 kg/ha of dry matter compared with 1 611 kg/ha inoculated. Only three out of 25 virgin soils gave good growth without inoculation of seed. Cloonan (1963) found that crown nodules on lablab were pink at 4 weeks, dark pink at 6 weeks, and black at 12 weeks and still active. He suggested that this feature might be used as a diagnostic check on successful strain inoculation.

Ability to spread naturally. Will not spread naturally.

Land preparation for establishment. Lablab performs best when drilled into a well-prepared seed bed, but it can establish by broadcasting into roughly ploughed or cultivated land if the seed is covered to some extent.

Sowing methods. It is drilled in 1-m rows into a prepared seed bed, or broadcast onto rough seed beds. In Brazil, it is commonly drilled in with maize at planting or when the maize is 15 cm high, using 20 percent by weight of lablab seed and 80 percent maize, in alternate rows 80 cm apart (Schaaffhausen, 1966).

It does not establish well in natural pastures unless they are cultivated. It can be sod-seeded into pastures (Mc Adam and Swain, 1969) with adequate fertilizer and preferably inoculated. In Brazil, it is sometimes broadcast from horseback into *P. maximum* pastures where the deep red latosolic surface is loose (Horrell, personal communication). Drilled rows allow interrow cultivation for early weed control. It is often sown with maize and sorghum in alternate rows for silage.

Sowing depth and cover. The seed germinates from sowing as deep as 10 cm, but it is usually sown at 2.5 to 5 cm and harrowed. Hand planting by dibbling in the seed or using a one-row hand machine is also practised.

Sowing time and rate. Five to 7 kg/ha drilled, with a heavier rate of 8 to 10 kg/ha broadcast. Sown in early summer, it will yield up to three grazings; later summer planting yields only one grazing.

Number of seeds. Per kg, 3 300 to 4 290 (per lb, 1 650 to 1 950). Percentage of hard seed is very low.

Seed treatment before planting. To break dormancy: not necessary. Inoculation with a cowpea type is advisable. Pelleting is not necessary unless to protect rhizobia, in which case rock phosphate should be used. Seeding with a neutral fertilizer will also protect the rhizobia. For insect and disease control, treat seed with dieldrin or endrin prior to sowing (to protect from bean fly).

Nutrient requirements. Generally in fertile soils, no fertilizer is necessary. In poor sandy soils, use 250 to 500 kg/ha molybdenized superphosphate and some potash if needed.

Toxicity levels and symptoms. There is evidence of an adverse effect of salinity on lablab (Wilson, personal communication).

Response to photoperiod and light. It is a short-day plant. In southeast Queensland, flowering commences in May; but if unfrosted, flowering may continue through the winter into the spring. Cv Rongai is later flowering than other types. It is sensitive to day length and flowers best with less than 11 hours of daylight; but it requires ample sunlight. In New South Wales, Murtagh and Dougherty (1968) got full light interception with a canopy of pure lablab. If grown with tall grasses or crops, it can climb to the light.

Compatibility with grasses and other legumes. It is usually sown alone or in widely spaced maize or sorghum rows because of its slow early growth and short life.

Ability to compete with weeds. Excellent when once established, but its early growth is slow and so it should not be subject to weed competition at this stage.

Tolerance to herbicides. No reference in the literature to this effect. Being a plant with broad-leaved tender foliage, it is probably highly susceptible to herbicide damage.

Vigour of seedling, growth and growth rhythm. Its seedling is vigorous, *Main deficiencies.* Its short life, low palatability of the stems and its susceptibility to frost.

Performance. At Fazendo el Prata, São Paulo, Brazil (Lambert, personal communication), *Lablab* raised the milk yield by 1.5 kg/day after two days. French (1937) successfully fed *Lablab* hay to sheep at Mpwapwa, Tanzania. In Brazil, on rotation pastures with *Lablab*, pigeon pea and grasses, 47 bulls gained an average of 40 kilograms per head in 63 days (Schaaffhausen, 1966). Hamilton (1969) obtained 9 to 13 litres milk/head/day from cows grazing pure dolichos.

Main references. Luck, P.E. (1965b); Morris, J.G. and Levitt, M.S. (1968).

Annex VI TOR for the continuation of work

Terms of Reference

for a state of the art report

"soil and water conservation in the Western Usambaras of Tanzania"

1. Introduction

Efforts on soil and water conservation of the Soil Erosion and Agroforestry Project (SECAP) started already in 1981. Later, a second initiative the Traditional Irrigation Project (TIP) joined this effort. Over a period of 16 years an enormous wealth of experience and knowledge could be obtained, and many activities were undertaken. Some of them turned out to be a success, others failed to find acceptance on-farm and in the rural communities.

During this period of time a lot of documents have been prepared: Evaluation and planning reports, case studies, trial and research reports etc. etc., and the knowledge is scattered in them. What is missing, is a concise compilation of all the experiences and findings which have been gained so far. In addition, SECAP may come to an end by the year 2000, its staff may be transferred to other places in Tanzania and abroad and thus the advisors, extension officers and others carrying this knowledge may not be accessible any more. A lot of it may be lost.

2. Objectives

The objective of the study is to document technologies and concepts on soil and water conservation based on the long term experience which has been gained by development projects, namely SECAP and TIP, in the Western Usambaras. They should become available to professionals and an interested public in Tanzania and in its neighboring countries. The knowledge compiled in this state-of-the-art-report should help other development programs in finding their own concepts and selecting the technologies appropriate for their site specific conditions. It should also help decision makers and politicians to formulate national soil and water conservation strategies and programs, which are urgently needed for Tanzania.

3. Terms of Reference

The task of the consultant covers in detail:

a) procure documents which are not available in the SECAP library. They may be available from former expatriate SECAP staff (R. Woyteck, R. Müller, T. Goebel, E. Locher, R. Pfeiffer etc.),

b) review documents and extract the relevant information from SECAP files, evaluation reports, studies and publications about Lushoto District,

c) write a draft report according to the outline attached in the appendix of the TOR,

d) discuss the draft report with project staff in a workshop in Lushoto of 2-3 days

e) include amendments, alterations, revise and finalize the state of the art report

f) submit a manuscript which is ready for printing.

All activities are carried out in close cooperation with SECAP staff. The work should be carried out in 1998. It is difficult to estimate the time requirements in advance. Therefore it is proposed to split the work into two contracts. In the first contract the activities a) to d) should be covered. A time period of approximately 2 months is considered necessary. Depending on the extent of additional work a second contract should be worked out.

Appendix: Draft outline for the "SECAP State of the art report"

Soil and Water Conservation in the Western Usambaras of Tanzania

Technologies and Development Concepts

(working title)

1. Introduction
   (justification, objective, scope and structure of the study)

2. History of the Usambara Mountains

3. Description of the Site
   (population, climate, vegetation, soils, water etc.)

4. History of SECAP Project

5. Technology Development

   5.1 Erosion Control
   5.2 Agroforestry
   5.3 Forestry
   5.4 Crop Husbandry
   5.5 Fruit trees
   5.5 Animal Husbandry

6. Concept Development

   6.1 Pilot Villages
   6.2 Catchment Approach
   6.3 Land Use Planning
   6.4 Forest Management Plan

7. Future Perspectives, Open Questions and Recommendations

Annexes

I Soil and Water Conservation
II Land-Use Planning
III Catchment Approach
IV Forest Management Plan

Terms of Reference for the elaboration of "technical papers" on production systems of field crops, vegetable production and animal husbandry

1. Introduction

Agricultural development in Lushoto has a long tradition and over the last twenty years several development projects supported this process: in the seventies the Lushoto Integrated Development Project (LIDEP), and later on the Soil and Water Conservation and Agroforestry Project (SECAP) and the Traditional Irrigation Project (TIP) worked in this field. In all these years many experiences were made, a lot of knowledge was obtained by agricultural advisors, but very little was documented and made available to newly posted extension staff. Apart from a few people in the district the agricultural knowledge of agricultural advisors is poor and accordingly their ability to give proper advice to farmers is limited. Training is one answer to the problem. Another one would be to supply field workers with good extension material

2. Objective

The objective of the Terms of Reference is to elaborate sound technical papers or small manuals on the existing production systems on field crops, vegetable production, animal husbandry, soil and water conservation and soil fertility maintenance.

3. Terms of Reference

The task of the consultant covers in detail:

* elaborate short, but concise technical papers on the most important aspects of crop and animal husbandry and vegetable production and soil fertility maintenance as given in the appendix,

* finalize the existing technical paper on soil and water conservation (SECAP/TIP 1995),

* discuss all the drafts in two three-day workshops at Lushoto with SECAP and TIP staff,

* include amendments, alterations, revise and finalize the technical papers,

* submit a manuscript which is ready for printing.

All activities are carried out in close cooperation with SECAP staff. The work should be carried out as soon as possible.

Appendix for TOR elaboration of "technical papers"

List of topics

Field crops

- maize
- beans
- potatoes
- wheat
- ?

Vegetables

- tomatoes
- cabbage
- onions
- carrots

Animal husbandry

- fodder production
- stall keeping

Soil fertility maintenance

- Composting and compost application
- mineral fertilizers
- green manuring

Annex VII Terms of reference of this study

1. Introduction

The Soil Erosion Control and Agroforestry Project (SECAP) in Lushoto has been engaged in Soil and Water Conservation since 1984. Initially the main emphasis was put on soil conservation through macro-contour lines, i.e. establish grass lines in combination with fodder bushes, fodder legumes and agroforestry trees. However, the initial concepts of a 2 meter wide macro-contour line was not adopted by the farmers (farmers complained that it takes too much space which could otherwise be utilized for crop production) and farmers did not plant grass strips along the contour. The grass strips proved inefficient on steep slopes because their spacing was too wide and the farmers did not decrease the spacing in between two strips. This led to a shift in policy of SECAP in 1992 when physical measures were introduced, i.e. bench terraces and Fanya Juu terraces. However, in many cases the soil in between the Fanya Juu terraces was already depleted and soil fertility was at a minimal level. The same applied to bench terraces where depleted soil formed the bed of the new terraces. The project has already taken steps to identify crops for green manuring and to improve soil fertility on newly constructed terraced land. However, these steps are at an initial stage only.

2. Objectives

The objective of the consultancy is to help develop and disseminate new practices of soil fertility improvement in combination with the existing soil-conservation measures in the Western Usambaras.

Therefore the consultant should find suitable crops and cropping systems to improve soil fertility on newly constructed terraces (fanya juu terraces and bench terraces). Based on these findings on how to improve soil fertility in fields under different soil and water conservation measures in a second part the consultant has to elaborate economically viable agroforestry, crop and animal husbandry options in combination with the soil and water conservation measures. These options should be elaborated with regard to the different agro-ecological zones of the Usambara Mountains. In a third part the consultant should then compare these options with the previously applied production systems of the farmers.

Simultaneously to these three steps the consultant in cooperation with project staff writes a state of the art report on knowledge and experiences in soil and water conservation gained so far in the Western Usambaras. Various members of project staff will contribute to the report according to their field of work.

3. Implementation

The work will be carried out by the consultant in several parts due to the fact that detailed TOR for part II and III as well as for the state of the art-report can only be defined in detail after the results of part I are available. The time schedule of the consultancy can be drafted as follows:

part I: Elaboration of suitable crops and cropping systems, preparation for state of the art report (February/March 1997),

part II: writing draft for state-of-the-art report (April to June 1997),

part III: finalize recommendations on suitable crops and cropping systems (including an economical evaluation) and finalize the state of the art report (October/November 1997)

4. Terms of Reference for Part I

The task of the consultant covers in detail:

a) Review existing literature and know-how of SECAP and of projects in other regions (e.g. Machakos/Kenya and Ruanda) with regard to past experience and trials on soil improving crops; screen results for the applicability in the different agro-ecological zones of the SECAP intervention area,

b) Conduct a small survey on farmer´s perception concerning type of crops and type of cropping systems that improve soil fertility in the field. Traditional agroforestry systems have to be considered when studying the improvement of soil fertility,

c) Identify additional agroforestry, crop and animal husbandry options that improve soil fertility and are combined with soil and water conservation measures. This has to be done with regard to the steepness of slope, different agro-ecological zones, rainfall pattern and farmer´s socio-economic considerations, The option of irrigation for the different crops has to be considered as well.

d) Scrutinise the recommended agroforestry crop and animal husbandry options for their suitability for various farming systems,

e) Collect and document data for the calculation of gross margin analyses for the recommended crops/cropping systems on terraces compared to traditional crops/cropping systems.

f) Draft a table of contents, an outline for writing the state-of-the-art report and make a detailed planning for implementation; the consultant together with project staff should decide on timetable and the distribution of work among the authors (who is writing which chapter),

g) Define terms of reference for parts II and III in cooperation with project staff and present an offer for the continuation of work,

h) Write a report on the activities a) to e).

All activities are carried out in close cooperation with SECAP staff.