Legume Diversification in Smallholder Tobacco Systems of Malawi: Climate Risk Management and Market Opportunities

End of Project Report

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Acronyms

APSIM	Agricultural Productivity Simulator
ARET	Agricultural Research and Extension Trust
BD	Bulk Density
CISANET	Civil Society Agricultural Network
C	Carbon
DAES	Department of Agricultural Extension Services
DUL	Drainage Upper Limit
GDP	Gross Domestic Product
GIS	Geographic Information System
HI	Harvest Index
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IDRC	International Development Research Centre
MARKSIM	
MGDS	Malawi Growth and Development Strategy
MPRSP	Malawi Poverty Reduction Strategy Paper
MRFC	Malawi Rural Finance
MMS	Malawi Meteorological Services
N	Nitrogen
NARS	National Agricultural Research System
NASFAM	National Smallholder Farmers Association of Malawi
NGO	Non Governmental Organization
OIBM	Opportunity International Bank Malawi
SAT	Semi Arid Tropics
SOC	Soil Organic Carbon
SON	Soil Organic Nitrogen
SOP	Soil Organic Phosphorus
SPSS	Statistical Package for Social Scientists
TBM	Total Biomass
TCC	Tobacco Control Commission
TOP	Time of Planting
PPL	Plant Lower Limit
UK	United Kingdom

Abstract

Tobacco forms the mainstay of the Malawian economy, and over 60% of NASFAM's small-scale farmers have relied upon tobacco as their main source of income. However, the tobacco industry in Malawi faces an uncertain future with fluctuating market demand and prices, coupled with increasing production costs. Tobacco production is associated with health hazards (high chemical and pesticide use) and environmental concerns (destruction of the Miombo woodlands for barn construction and curing sheds). In the face of these negative aspects, ICRISAT is committed to working with NASFAM in assisting its members to diversify their cash crop base into high value groundnuts for which there are lucrative national, regional and international markets. This project – funded by the International Development Research Centre (IDRC) – on diversification was aimed at generating information and knowledge upon which an intensive diversification, dissemination and support programme for NASFAM could be based. The general objective was to strengthen the technical capacity of NASFAM and the Meteorological Department in supporting smallholder farmers who wish to diversify their cash crop production out of tobacco with groundnut. Main specific objectives were to: 1) Document the advantages and disadvantages of tobacco farming from a livelihoods, health and environmental perspective; 2) Synthesize existing information on proven and potential groundnut value-chains; 3) Characterize and map out the impact of temporal and spatial climate variability and key environmental and socio-economic parameters on groundnut productivity and production risk; and 4) Synthesize and integrate the research outputs from the first three objectives. The research involved a desk study, a field survey, and crop simulation modelling. High costs of production, mainly due to high costs of labour, fertilizer and pesticides, heavy taxation through levies, strict quality requirements, and compromised gross margins due to a non fully liberalized auction marketing system emerged as the major drawbacks associated with tobacco farming from a livelihoods perspective. Environmentally, tobacco farming was cited as being a major culprit in environmental degradation, as evidenced through wanton deforestation, pollution of air, soil and water resources through burning of residues, and use of high doses of chemical fertilizer and other pesticides. From the health perspective, the research pointed out a wide range of ailments including nicotine poisoning (green tobacco sickness), pesticide exposure, respiratory effects, flu, general body pains, musculoskeletal pains and other injuries as being among the main hazards arising from tobacco farming. Groundnut field trials confirmed the significant effects of agronomic practices such as time of planting and plant population in determining grain yield. Crop phenology trials assisted in calibration of the APSIM Model using five main groundnut cultivars in Malawi. However, the evaluation of APSIM performance for total biomass (TBM) and resultant yield predictions and effects of crop management could not be completed due to model inadequacy in explaining some of the results from the simulations. Demonstration of the value of combining field experimentation and modeling in generating recommendations for improving crop productivity and economic returns to investment in crop production also emerged as a critical achievement of the project. The research also led to development of a template for comparing crop management options within and across sites in order to simulate yield under different production domains coupled with economic analysis. Groundnut yield data generated field trials that provided different farmer scenarios from which any farmer situation can be simulated and recommendations drawn. The risk analysis can also be done through use of the APSIM Model. Due to the short nature of the project we recommend that IDRC provide more than one phase for such detailed research to be completed.

Keywords: APSIM, diversification, gross margin, groundnut, MARKSIM

1 The Research Problem

The rural population of Malawi faces chronic food and nutritional insecurity, which urgently calls for innovative agricultural solutions that can provide both income as well as food, without further eroding the natural resource base. According to recent surveys subsistence agriculture accounts for 63.7% of income (MPRSP, 2002).

For many years, tobacco has been the mainstay of the Malawian economy providing the much-needed foreign currency that underpins the value of the Kwacha, but the fluctuation in tobacco prices has dealt a big blow to many tobacco growers (Financial and Economic Review, 2006). This has also affected the country in terms of total revenues that have continued to decline with the decline of tobacco prices. The repeal of the Special Crops Act in the 1990s which had prohibited smallholder farmers from growing specialized cash crops led to a massive increase in tobacco production, particularly of the burley type. However, with the liberalization of the marketing of agricultural inputs and produce, which resulted in withdrawal of subsidies on fertilizer, the production of tobacco has become less economical. Both yield and quality of the leaf have declined in recent years and this has fuelled a cycle of low leaf quality - low prices - low inputs - and reduced acreage. There has also been increasing competition from neighbours such as Mozambique, who can offer multinational companies various incentives including large tracts of unexploited land for tobacco production.

On a distressing note, tobacco production has been identified as the leading factor in natural resource depletion, primarily of indigenous Miombo woodlands for curing and for barn construction. This has continued despite the existence of laws and regulations that dictate that for each unit area under tobacco, there must be a certain area put under forestation. Such regulations have deliberately been flouted by the estate sector in the interest of profits, and have been difficult to implement in the smallholder sector due to limited land resources available for the establishment of woodlots. Therefore, the future lies in the improvement of productivity and widespread adoption of alternative crops that can replace tobacco or make farmers less vulnerable to price fluctuation in the tobacco market.

The search for alternative cash crops has received considerable attention in recent times, with a study from the Central Region of Malawi identifying groundnut as an appropriate alternative cash crop to tobacco in this region (Edriss, 2003). However, the dilemma facing policy makers is how to reduce the dependency on tobacco through crop diversification without further degrading the natural resource base, and without depriving the already poor people of an income generating opportunity.

Tobacco is the mainstay of the economy in Malawi, accounting for over 70% of export earnings (Financial and Economic Review, 2006). Tobacco is produced in most areas of the country, except the Shire Valley, low altitude lakeshore areas, plateaus and the highlands. Malawi is therefore faced with the immense challenge of transitioning from total reliance on a tobacco-based economy and its concomitant loss of revenues and foreign exchange to a more diversified economy with multiple sources of livelihoods for smallholder farmers (MGDS, 2006). In 2000 there were about 61,800 registered estates that were producing the more capital intensive flue-cured tobacco, but by the 2005/06 season the number had declined to around 40,000. Over the same period the smallholder sector experienced growth in the number of tobacco farmers from 17,200 to an estimated 28,000 as a consequence of the repeal of the Special Crops Act and continued demand for burley tobacco. The decrease in the number of estates was due to the global decline in demand for flue-cured tobacco and an increase in demand for burley tobacco that now dominates production by smallholder producers (Financial and Economic Review, 2006). Unfortunately, prices have fallen from an average USD 1.60/kg in the 1990s to less than USD 1.00/kg in the 2006 selling season when the production cost for burley tobacco was $ 1.22/kg. But this subsequently increased as a result of increased labour and fertilizer costs. As a result there was a significant reduction in total proceeds, reduced employment, and stagnation in the rate of economic growth. Several quality issues such as the strict enforcement of the “Non-tobacco related materials” coded by the tobacco buying companies; and the regulations banning the use of child labour in tobacco production are also thought to have contributed to the declining production trends observed in Malawi. Besides all these problems, environmental problems (deforestation of the Miombo woodlands for tobacco curing sheds and barn construction, the use of large amounts of pesticides and chemical fertilizer in tobacco production) have serious implications on ground water pollution and other associated health concerns. In addition, the high input levels required for tobacco production indicate an urgent need to diversify into other crops that partly address these problems while at the same time providing cash to farmers.

In most tobacco growing areas farmers also grow grain legumes, especially groundnuts, because of a ready market where money can be got while waiting for the tobacco marketing process that takes several months to become operational. As a way of assisting farmers to cope with uncertain tobacco prices, NASFAM had for the past five years intensified promotion of grain legumes and because of initial success with groundnut production and subsequent certification by Fair Trade, more emphasis was given to groundnut production for diversification in the tobacco growing regions. However, there are five key issues that need investigation for NASFAM to increase groundnut production. The questions that need investigation are:

- What are the production, marketing, institutional and policy constraints that currently need to be addressed for grain legumes to contribute more in filling the potential void left by the tobacco sector?
- Despite all the research and technology development over the past decades what is it that needs to be done to improve the yields of grain legumes to attain full yield potential?
- How best can grain legumes be integrated into tobacco production – with relay cropping, sequential cropping systems, rotations or total tobacco substitution?
- What are best-bet legume innovations that should be targeted towards the differing soil and climatic conditions that exist in the smallholder farmer sector across Malawi? What are the innovations that have *a high probability of production and economic success* (and hence adoption) in the context of long-term climate variability?
- Can grain legume production help to ameliorate the natural resource degradation commonly attributed to tobacco and hence assist, sustain, or even increase, the yields of the staple food maize and other crops in the rotation?

2 Objectives

The general objective of the project was to strengthen the technical capacity of NASFAM and the Meteorological Department in supporting smallholder farmers who wish to diversify their cash crop production out of tobacco into groundnuts. The specific objectives were to:

1. Document the advantages and disadvantages of tobacco farming from a livelihoods, health and environmental perspective, and show how diversification into groundnut can mitigate some of the identified disadvantages of tobacco farming;
2. Synthesize existing information on proven and potential groundnut value-chains to identify opportunities and constraints in local, regional and international markets;
3. Characterize and map the impact of temporal and spatial climate variability and key environmental and socio-economic parameters on groundnut productivity and production risk to identify more precise recommendation domains for groundnut diversification strategies that have a high probability of success; and
4. Synthesize and integrate the research outputs from objectives one to three and solicit

2.1 Feedback on the research that would be used to finalize the research report

With funding from the International Development Research Centre (IDRC), ICRISAT and NASFAM carried out studies on tobacco and groundnut in order to explore and document the merits and demerits of tobacco farming from a livelihoods, health and environmental perspective, and suggest strategies on how groundnut could be positioned in diversification strategies out of tobacco production systems so as to mitigate the identified disadvantages of tobacco farming.

3 Methodology

The project undertook a number of activities in order to achieve the project objectives. The range of activities undertaken included: a desk study on existing information on tobacco and other cropping systems in the project target region, a field survey and a rapid follow-up survey to elicit views of smallholder farmers on the tobacco-dominated farming system in the project area and studies on crop simulations on expected outcomes of diversification scenarios based on actual field data using the APSIM model. A summary of specific methods and procedures employed in the studies are highlighted by objective in the sections that follow.

3.1 Specific objective 1

Document the advantages and disadvantages of tobacco farming from a livelihoods, health and environmental perspective, and show how diversification into groundnut can mitigate some of the identified disadvantages of tobacco farming

The main activities under this objective were a desk study coupled with a field survey and a follow-up rapid survey initiated to fill all gaps on the issues that were deemed as having not been thoroughly addressed in the main field survey. In the desk study, key research documents relating to tobacco and groundnut were sourced for review from various institutions involved with the crops. This stage also involved consultations with key stakeholders and key informants including main value chain players in the tobacco and groundnut industry.

The field survey used two approaches: 1) Individual interviews; and 2) Focus group discussions. Both men and women were involved in areas where NASFAM has operations in Kasungu and Lilongwe districts. With the understanding that men are primarily involved in tobacco production, and women currently are the primary producers and marketers of groundnut, both formed an important target of the survey. Six focus group discussions were done in each one of the study areas. Three types of groups (men only, women only and mixed) constituted the focus groups. This enabled the study team to capture some information that would not have been received during the mixed gender discussions due to the tendency of some individuals to either dominate or remain shy during discussions of this nature.

A structured questionnaire was used for the individual interviews. A 10% proportion of the paid up NASFAM members in the study sites were selected using multi-stage sampling procedures to constitute the sample for the household interviews. A checklist with key information required was also designed for the focus group discussions and interviews with key informants. The main areas of focus in both the group discussions and household interviews included: producer characteristics, production aspects of groundnut against that of tobacco in the areas of interest, production constraints, marketing and pricing, marketing constraints, storage and handling of the crop, utilisation issues at household and national levels, input use for the different grain legumes and tobacco, profitability of the crops, institutional support, policy issues with regard to the crops in question, and health issues related to both tobacco and groundnut. Other aspects of the farming systems studied were: the impact of tobacco on environmental resources focussing on deforestation and land degradation, issues of child labour and social displacement especially migrant labourers to various farms as a form of employment, information on the costs of production of groundnut and tobacco was sourced and comparative analyses undertaken to determine whether the former provides a viable alternative to tobacco production, and what factors need to be addressed to improve returns to smallholder farmers.

All data was analysed using the Statistical Package for Social Scientists (SPSS) and Microsoft Excel. The idea was to determine the definitive justification for, or against, groundnut diversification in tobacco production systems.

3.2 Specific objective 2

Synthesize existing information on proven and potential groundnut value-chains to identify opportunities and constraints in local, regional and international markets

While the value chain analysis for tobacco has been done, very few studies have been done on groundnut. This was therefore undertaken by NASFAM with input from ICRISAT through tracking of all production aspects including seed systems, access to inputs and the application costs, cost of production and gross margin analyses, post-harvest processing and quality management, marketing structures and key players in the marketing of groundnuts, and tracking of commodity all the way to consumer preferences. This was done in the context of development of the groundnut sector for the Malawi market, as well as the regional and international export markets. Information on production was collected from farmers in the two study sites. More information was collected through meetings and discussions with the key players along the value chain (middlemen, traders, processors, exporters and consumers).

A value-chain analysis was done to understand market competition, movement of groundnuts from the producer to the consumer, and current and potential competitors. The outcome of the value-chain analysis was the identification of bottlenecks, opportunities that can be exploited, and the mitigation of factors that might act against the positioning of groundnuts as an income-generating crop in the smallholder farming-sector. This information would prove useful while taking decisions on points of intervention. The value-chain analysis would also enable analysis of marketing efficiency in pricing at each point following the tracking of prices and costs at specific points along the value chain and hence improve understanding on the costs which could be reduced or eliminated completely.

3.3 Specific objective 3

Characterize and map the impact of temporal and spatial climate variability and key environmental and socio-economic parameters on groundnut productivity and production risk in order to identify more precise recommendation domains for groundnut diversification strategies that have a high probability of success

The work to address this objective was led by the Malawi Meteorological Services (MMS) in close collaboration with ICRISAT and the University of Reading. Key activities in this regard included: 1) Collection of long-term daily climate data (30 years +) from MMS satellite weather stations, and soils survey information for the target areas of this project; 2) A survey of 'volunteer' rainfall stations (large estates, district offices, schools and churches) in the project area in order to expand and improve the spatial distribution of climate records (which would then be available to this project), and then collect, clean and computerize available rainfall records; 3) Validation of MARKSIM (a spatial weather generator) for parts of the project area for which no climate data exists, which further generates daily weather data (temperature and rainfall) for tropical conditions as opposed to the Markov models that have been successfully used at temperate latitudes where frontal weather is the main driving force (Jones *et al.*, 2002); 4) Validation of the Australian-developed weather-driven crop growth simulation model (Agricultural Production Simulator, APSIM) in order to calibrate it for local use on groundnut in the current and any follow-up studies. Previous work on modelling in Malawi was done using the CERES-Maize model and mainly for maize (Sing *et al.,*1993; Thornton *et al.,* 1993; Saka *et al.*, 1997). The data for calibration of the APSIM Model was sourced from phenology trials and the simulation modelling used data from trials on factors of production including time of planting, varieties, and row spacing. These trials were run at both on-station and on-farm sites. 5) Applying APSIM to identify groundnut interventions that have a high probability of production and economic success in the context of climate and soil variability that exists in the project area; and 6) Combining the outputs above with relevant socio-economic parameters (using GIS) to determine targeted recommendation domains for legume diversification strategies.

The choice of the APSIM model was based on the experience of ICRISAT researchers involved in the work, and the fact that several parameters for this model have been developed in tropical environments and tested in eastern and southern Africa. This was the reason for only undertaking the simple validation process suggested in the proposal. The model had been designed for use on a wide range of crops including groundnut that would make it easier to adapt for simulation under Malawi conditions.

This work would additionally have direct relevance and further enhance other initiatives that had already been initiated over the past year (and then entering the second year pilot phase) in a collaborative approach between NASFAM as producers, the Opportunity International Bank of Malawi (OIBM) and the Malawi Rural Finance Company (MRFC) as micro-finance institutions, and the Insurance Association of Malawi (a consortium of several insurance companies) with support from the World Bank to provide insurance services to smallholder farmers against the impact of drought on loan repayments.

The work involved extensive farmer-managed field trials as well as on-station research trials. Design aspects ensured that two on-station trials, one at Chitedze Research Station representing the tobacco and groundnut production areas found in Mchinji, and the other trial at the Agricultural Research and Extension Trust (ARET) research station at Mwimba representing the Kasungu area, were conducted. The on-farm trials had a subset of the same treatments as used in the on-station trials with a single replication on each farm. On-farm trials were chosen based on agro-ecology and proximity to roads as they also served as demonstrations. The agronomic trials were aimed at providing the important function of local calibration of APSIM, but also served the added purposes of i) identifying major groundnut production constraints as well as ii) demonstrating the impact of alternative crop and soil management innovations to farmers and farmer groups.

3.4 Specific objective 4

Synthesize and integrate the outputs obtained from Objectives 1-3 and present them at an end of project workshop to key project stakeholders for comment and feedback.

Drawing upon the outputs of the activities associated with the first three specific objectives and the synthesis undertaken thereof in objective 4, ICRISAT and project partners convened a meeting of relevant stakeholders (government policy makers from the Ministry of Agriculture, research partners, and Representatives of District Assemblies). The key findings of the project were presented to this group in order to obtain their comment and feedback. The end of project workshop was expected to identify and agree upon the key components of a focused and extensive dissemination initiative aimed at greatly enhancing groundnut production in view of diversification out of the tobacco dominated farming system.

4 Project Activities

Main activities undertaken to meet the project objectives were a desk study, a field survey and calibration of Agricultural Productivity Simulator (APSIM) and crop simulation modelling.

4.1 The desk study and field survey

The desk study involved reviewing of key research documents relating to tobacco and groundnut. Furthermore, consultations with key stakeholders, key informants, and key players from both the tobacco and groundnut industries were held. The outcomes of the field survey were used in identification of two main issues to guide diversification efforts: i) key constraints along with suggested approaches to resolve the challenges of improving productivity and quality of groundnuts to make it suitable for smallholder farmers; and ii) the interventions necessary to resolve the marketing, institutional and policy challenges faced by the groundnut sector.

The desk study and the field survey were conducted in order to document the advantages and disadvantages of tobacco farming from a livelihood, health, and environmental perspective. At the same time, objective 2 further sought to study the value chain for groundnut in the domestic, regional and international markets.

4.1.1 Advantages and disadvantages of tobacco farming

The main objective of the desk study was to document the advantages and disadvantages of tobacco farming. The advantages and disadvantages were to be looked at from a livelihood, health, and environmental perspective.

4.1.1.1 Livelihoods

The desk study revealed that tobacco has the advantage of being the most important crop for Malawi's exports. The study found that tobacco earns up to 76% of foreign exchange, employs up to 86% of the country's labour force and contributes around 23% to Gross Domestic Product (GDP). This therefore, makes Malawi highly vulnerable to adverse or negative developments pertinent to tobacco emanating from within the country or the African region or internationally.

Furthermore, the study found that 60% of tobacco farmers and 53% of groundnut farmers reported that they normally have food lasting the whole year reflecting that tobacco contributes to the food security situation to some extent. Probably, the farmers use the income from tobacco to buy fertilizer for the maize and hence have increased maize yield.

The study also found that the price for tobacco seed was currently at MK25/g and that 5g of seed is required to grow 1 hectare of tobacco. This translated into MWK125 (USD 0.83) per ha. This ends up reducing the cost of production for the farmer. Eventually, the money saved contributes to other livelihood uses for the farmer.

The study established that tobacco probably enjoys the best crop commodity marketing system in Malawi, based on the auction system and that auction sales open from around March/April and proceeds to September/October, the length of the marketing period purely depending on the anticipated size of the crop, any sale stoppages due to price conflicts, congestion created by unscheduled deliveries and storage capacity of the buyers. The announcement for the opening and closing of the auction floors is made by TCC. It was found that tobacco has an elaborate policy at all levels that regulate production, marketing and export of the crop.

Despite tobacco having the advantages stated above, it has notable disadvantages at the household and national or global levels. At the household level, farmers cited low prices (66% of the tobacco farmers), strict quality requirements (19% of farmers) and delayed sales due to congestion at the floors (16% of the farmers). Unlike the scenario with groundnut where the price given to the farmer is the ultimate income that he gets, tobacco suffers a lot of deductions (levies), and 15% of tobacco farmers in the survey mentioned that they have several deductions which reduce the income they could have received from tobacco sales. In fact all farmers pay the designated levies on their tobacco. High transaction costs such as grading and transport to the auction floors, complex crop grades, such as those for flue-cured tobacco, with more than a hundred grades and burley with more than 40 grades are some of the cost inflating processes that dupe farmers.

The field study looked at labour issues for the crops in question and found that more tobacco farmers (49%) used hired labour as opposed to groundnut farmers (35%) reflecting higher labour demand for tobacco. This excessive demand for labour depletes the farmers' labour investment which could have been used for other livelihood activities. Hired labour contributes to the total cost of production and reduces the margins realized by the farmers. In the event of crop failure and low prices it contributes to hunger as some farmers completely ignore maize hoping they will use the proceeds from tobacco to buy maize. Tobacco in estates is mostly grown on leasehold land. This land cannot be used for production of food crops and can be rented for as long as 20, 50 or up to 99 years. This reduces the amount of land that can be used for food production.

Much of the land allocated to the lease system in tobacco estates is often left idle and irks the people earning a living on the adjacent customary land (which is diminishing) and hence people are tempted to encroach on such leased land. Government has in some cases, particularly in the Namwera and Mangochi areas, acquired some of that land and redistributed it to families from the high population density areas of Thyolo, Mulanje and Phalombe to be used for farming purposes.

4.1.1.2 Health

Literature states that the harmful health effects arising from tobacco production include nicotine poisoning (green tobacco sickness), pesticide exposure, respiratory effects, musculoskeletal and other injuries (Arcury and Quandt, 2006). Forty-two percent of tobacco farmers interviewed in Malawi mentioned that tobacco production has had some effect on their health. The main problems mentioned were flu and general body pains. However, recent and detailed medical studies on effects of tobacco farming on health in Malawi are lacking and hence there is a need to establish and quantify the effects of tobacco production on producers.

4.1.1.3 Environment

Tobacco residues which are burnt in order to eliminate the risk of harbouring some pests and diseases for the crop lead to environmental degradation. This is totally in contrast with groundnut whose residues ensure that the problem of soil fertility is being addressed. Some farmers intercrop groundnut with maize which helps to reduce weeds and moisture loss, apart from the maize benefiting from the fixed nitrogen. Unlike tobacco, groundnut residues have various beneficial uses. They are used to make compost manure (reported by 42% of the farmers), or directly incorporated into the soil to improve soil fertility (reported by 33% of the farmers), or used as animal feed. Another area of concern in tobacco is the use of pesticides, particularly in the estate sector in Malawi, inclusive of the tobacco estate sector. The persistent use of obsolete pesticides and containers pose a danger to the environment. This happens due to leftover or unused chemicals from season to season beyond the period that it should have been used due to over-purchase, under-use or even wrong purchases or changing farm enterprise or cropping systems. Furthermore, tobacco has been described as a major contributor to environmental degradation, particularly from the use of fuel wood for curing and the high demand for poles for construction of curing and grading sheds. Agricultural land increased from 3 million hectares in 1976 to 4.5 million in 1990 (over 100,000 hectares opened every year on average and close to 300 ha opened every day). The use of pesticides and other chemicals affect the ecosystems and other chemicals are said to be depleting the ozone layer.

5 Can Groundnut Mitigate the Disadvantages Associated with Tobacco Farming?

Grain legumes have several attributes that make them attractive to small-scale farmers in Malawi, especially women. They are: 1) Grain legumes are easily grown by women. They are generally considered women's crops since women are mostly involved in their production and sale; 2) Human and livestock nutrition: groundnut can be processed into products, such as peanut butter, cooking oil, snacks and groundnut flour; and groundnut meal can be used by the livestock industry; 3) Food security and mitigation of worsening rural poverty as they mature early and marketing starts before commencement of tobacco sales; 4) Grain legumes provide an opportunity for crop diversification and food security; 5) It is well-established that not all the grain legumes are sold during the marketing season, but are kept as a 'bank' to draw upon at times when ready cash is needed to purchase food supplies; 6) It improves soil fertility. Most grain legumes, in the presence of adequate soil phosphorous and micro-nutrients, fix substantial amounts of nitrogen from the air through the activity of *rhizobia* that colonize root nodules in the soil. Through this mechanism, they are not affected by low nitrogen levels prevalent in the depleted soils in the same way as non-leguminous crops. This makes them attractive crops to grow in various crop rotations with non-leguminous crops, including maize and tobacco. This has been demonstrated by the cropping systems in southern Malawi where pigeonpea has been intercropped with maize for decades. As the legume crops are harvested most of these nodules remain in the soil; 7) Low usage of pesticides causes minimal pollution of the soil and water resources emanating from pesticide use; 8) Groundnut does not require wood, either for construction of curing barns or as firewood for curing flue cured tobacco. This will reduce the rate of deforestation which is partly attributed to the tobacco industry. A further advantage can come from the leguminous foliage residues that remain on the soil surface at harvest, which can help maintain soil organic matter and soil structure. However, there are competing claims for legume residues, which are priced as animal fodder and are often removed from the field.

In a study conducted by CISANET with NASFAM in 2009 to work out realistic farm gate pricing, it was established that the most vulnerable crop was tobacco due to its high input costs and use. The smallest decrease in gross margin ($ /ha) was observed in groundnut (8%), followed by maize (27%), and then rice (37%), which was followed by cotton (44%), and lastly, tobacco, whose gross margin had the largest decrease due to price changes (61%).

The same study found that groundnut does not have a single established market where farmers take their groundnuts for sale. Instead, several buyers participating in the marketing of groundnuts in the areas of this study followed the crop at the door step of the farmer. This in itself reduces the marketing cost, thereby making groundnut margins higher. The higher gross margins therefore, present groundnut as an attractive alternative to tobacco in Malawi. The research also found that with any increase in productivity of groundnut, gross margins become even more attractive. Therefore, following the options proven by the field trials data where early planting of groundnut, optimal plant population, and good choice of varieties resulted in increased yield, all put groundnut as the best alternative among the crops studied. The task ahead is only to increase productivity which will increase profitability. Once made attractive, groundnut farming has the potential to reverse the negative impact of tobacco in that it does not involve much use of wood. This saves the trees which would not happen if tobacco continues. On health, the ailments that result from tobacco farming could be avoided if farmers adopted groundnut farming as the main cash earner.

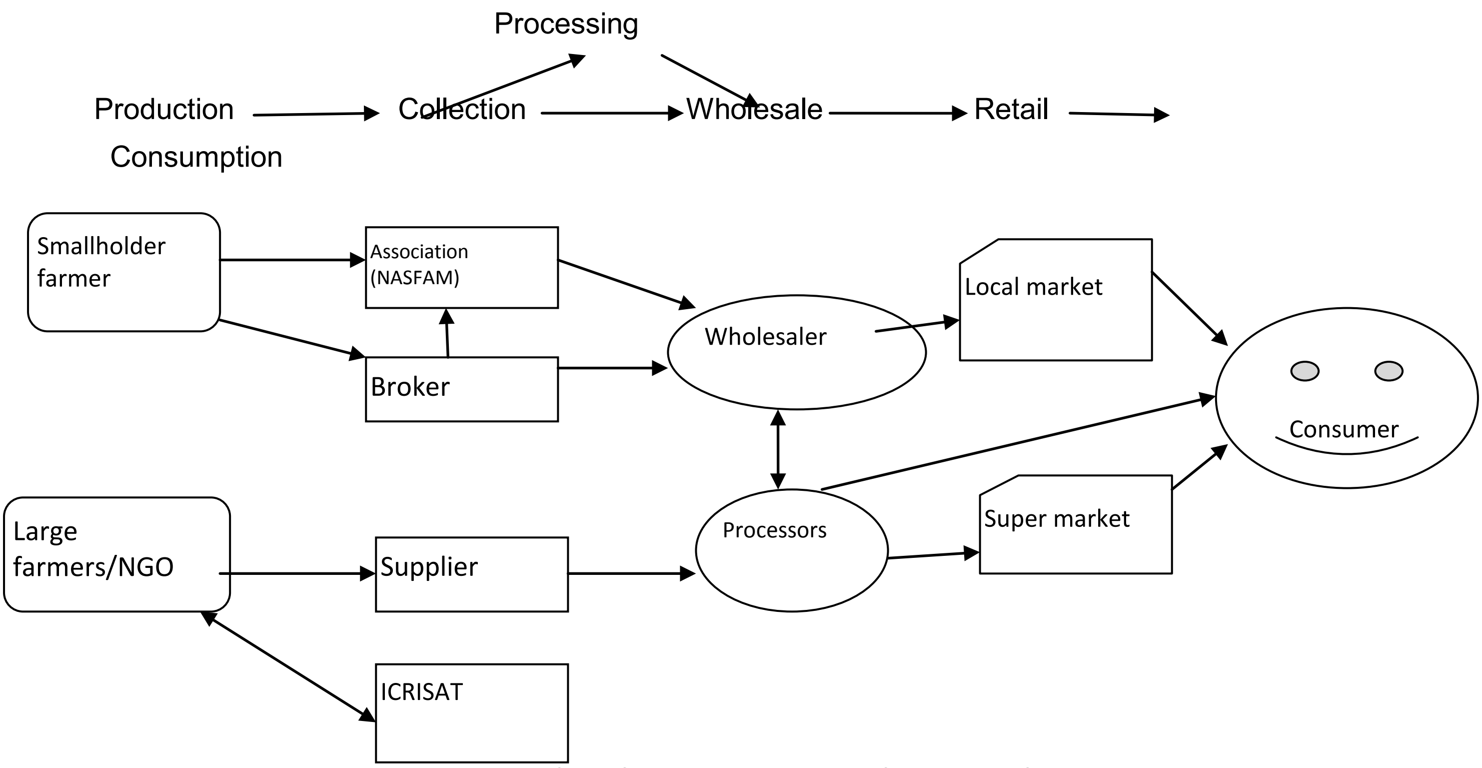
5.1 Identification of the opportunities and constraints in local, regional and international groundnut markets

The information collected through the desk study and the field survey was synthesized in order to understand the opportunities and constraints along the groundnut value chain. It was found that the development of short and medium duration and high yielding groundnut varieties had really boosted groundnut productivity since the early 2000s. CG7 and Nsinjiro varieties for oil and confectionary respectively, have been identified as the most high yielding groundnut varieties. These varieties have a yield potential of up to 2500 kg/ha. However, most smallholder farmers generally obtain an average of 800 kg/ha. The desk study identified a number of constraints leading to low crop productivity in general and then specifically looked at the ones pertaining to groundnut. The study found that groundnut productivity is constrained by: 1) Low access to production capital and financing; 2) Low quality planting seed; 3) Poor agronomic practices (poor land preparation, inappropriate crop population due to ridge and plant spacing, late planting, late weeding, poor pest and disease control; and 4) Land degradation due to the small quantity of arable land available or wrong use of land. The household survey however, highlights that farmers blame the low groundnut productivity on: 1) Limited access to improved varieties (reported by 30% of the respondents); 2) Low cash value of the crop (reported by 43% of the respondents); 3) Unfavourable climate (reported by 26% of respondents); and 4) Lack of management skills (reported by 15% of respondents).

Due to lower yields per unit area, farmers expect to maximize their returns using the prices given per unit. The study further found that seed is another key constraint in groundnut production as poor seed affects levels of productivity. Farmers' Associations, such as NASFAM, therefore needed to continue working with research organisations such as ICRISAT to ensure that they access the required seed in the right amounts at the right time. Use of improved seed would improve levels of productivity and thus increase returns. The new varieties have the advantage of having been developed for specific agro ecological zones in Malawi to avert the challenge of unfavourable climate. There are now short and medium duration varieties with preferred market and farmer traits. The study also showed that groundnut yields are further reduced due to poor soil fertility and a lack of knowledge on the benefits of applying fertilizer in groundnut fields. Farmers stated that they do not apply fertilizer to the groundnut crop as they believe it does not need it. Therefore, this means that there is a need to educate farmers on the importance of planting groundnuts on fertile soils or on enhancing soil fertility by applying fertilizers if they are to get good yields. Besides low soil fertility, low plant populations further reduce yields.

The study therefore implies that it is vital that productivity issues be addressed as a matter of priority so that more land can be released for purposes of diversifying into other enterprises. Diversification without any improvements in productivity will not yield any significant impacts as productivity enhancement could be the only means of increased revenues for smallholder farmers as the sensitivity analysis of the gross margins showed.

The information gathered from the desk study and the field survey provided insights into the groundnut value chain at the time of the study. Information was gathered on production, grain collection, processing, wholesaling, retailing and consumption. Furthermore the flow of the groundnut products from one player to another was identified. Information was also collected on support functions such as input supply, financial services, transport and packaging. The information therefore indicates that the groundnut value chain has a number of players but the most direct ones are farmers, brokers (middlemen otherwise called vendors), big buyers, processors, wholesalers, retailers and consumers. Each of these players has got a direct function in the chain. It was found in the study that the production function is carried out by farmers, while brokers, associations and big buyers are responsible for collection (assembling). On the other hand wholesaling is carried out by wholesalers and processors with retailing being carried out by local and supermarkets. The flow of products from one player to another is tracked by marketing channels.



Note: The activities listed on top of the figure are the direct functions of players in the chain

Figure 5.1: A typical value chain for groundnut developed from the information collected from the desk and field studies

The study indicated that ICRISAT is the leading institution in groundnut research in Malawi although it is the NARS that is mandated with conducting research in groundnut. This happens because this institution has limited resources to carry out most of the multi-site experiments. The NARS also collaborate with other partners such as NGOs in order to provide technical backstopping in groundnut research. ICRISAT in collaboration with NARS has developed a number of groundnut technologies ranging from good agricultural practices to development of early and high yielding varieties.

It was also revealed in this study that the major extension service provider along the groundnut value chain is the Ministry of Agriculture and Food Security through the Department of Agricultural Extension Services (DAES). These are located in all groundnut producing areas and cover other crops as well, unlike the specialization existing in the tobacco sector. Other extension providers are the Association Field Officers in the NASFAM system and other staff from the NGO sector. The extension officers are given capacity building training by ICRISAT. However, the challenges are: poor resource support in the public sector extension service, large numbers of farmers, and other issues, such as literacy rates.

5.2 Characterisation and mapping of the impact of temporal and spatial climate variability and key environmental and socio-economic parameters on groundnut productivity

The major activity here was climate data collection led by the Malawi Meteorological Services (MMS) Department in close collaboration with ICRISAT and Reading University (UK) and Validation of APSIM Model for Malawi (led by ICRISAT). The APSIM Model validation involved on-station trials which were conducted at Chitedze and Chitala Research Stations and Mwimba farm institute. The trials were of two types including: the groundnut phenology trial and effect of special and temporal management practices trial.

5.2.1 Groundnut phenology trial

Five groundnut varieties were used in the phenology trial. These included: Chalimbana, CG 7 and Nsinjiro (Virginia types), and Kakoma and Chitala (Spanish types). The trial was conducted at Chitedze and Chitala Research Stations with three replications.

Results on kernel yield showed no significant differences ($P \leq 0.05$) between varieties at both Chitedze and Chitala Research Stations, a situation that was not consistent with the general experience – the yield potential of Virginia types is usually supposed to be higher than of Spanish types because of the ability to utilize the length of the growing season by the Virginia types due to their longer duration. However, in this trial, the Spanish types (Kakoma and Chitala) out-yielded one of the improved Virginia types (Nsinjiro) at Chitedze and both CG 7 and Nsinjiro at Chitala site. These results could be attributed to the fact that the Spanish types had escaped the effects of the early season dry spells that occurred in the test season. It is becoming evident though that rainfall onset in many parts of the country is getting more and more erratic, therefore, high yielding Spanish type of varieties could be better adapted to the changing rainfall patterns and provide hope for productivity gains in future.

Highly significant differences were, however, observed for canopy height and canopy diameter ($P \leq 0.001$) and ($P \leq 0.003$), respectively, at Chitedze. Similarly significant differences ($P \leq 0.001$) and ($P \leq 0.001$) were observed for canopy height and canopy diameter respectively at Chitala. These differences in canopy height and canopy diameter are consistent with the fact that these two types of groundnut have different botanical characteristics; the Virginias tend to be shorter (spreading stems) while the Spanish types have taller (erect) stems.

Varieties also showed highly significant ($P \leq 0.001$) differences on "Days to 50% flowering" between varieties; the Spanish types flowered earlier than the Virginia types, thus again escaping any effects of soil moisture stress during critical growth and reproductive stages. This was observed both at Chitedze and Chitala Research Stations. However, another important observation was that even with the same type, the varieties flowered earlier at the lower altitude site (Chitala) than at higher altitude at Chitedze. The higher temperatures at the lower altitude are likely to have accelerated phonological development.

These results, therefore, were confirming that variety type and temperature, both matter in determining groundnut productivity and time to flowering and hence time to maturity. These factors therefore are important in modelling of groundnut productivity.

5.2.2 Determination of the effects of spatial and temporal management practices

This activity included determination of the effects of Ridge spacing, Time of planting, and two groundnut varieties. Ridges were spaced at 75cm, 90cm, and 120cm. The 120 cm row spacing was included because it is the spacing used by tobacco farmers when these fields are grown to groundnuts in the next year, with the farmers using the same ridge spacing and hence the implications on yield. Four different "Time of planting" treatments were selected in this experiment, with one week intervals between the subsequent plantings after the first one. These were selected to reflect the actual practice of the farmers after the onset of the season, considering their preferences for which crops need to be sown at onset of rains and other crops whose planting can be delayed without great losses in yield. In Malawi, farmers grow two predominant types of groundnut varieties: Virginia or long season varieties, and Spanish or short season erect varieties. The trial therefore, consisted of one Virginia (CG 7) and one Spanish type (Kakoma); these were chosen based on prior knowledge of their wide adoption by farmers in the target districts. All the necessary data were collected and analysed using the GENSTAT Statistical package.

Results for the 2008-09 rainy season showed significant differences ($P \leq 0.006$), ($P \leq 0.001$) and ($P \leq 0.001$) between treatments (Ridge spacing, Time of planting, and Varieties) on kernel yield, at the Chitedze site. Highest yield (2529 kg ha $^{-1}$) was obtained at 75cm Ridge spacing, followed by 90cm (2428 kg ha $^{-1}$) and lastly by 120cm (1712 ha $^{-1}$) row spacing.

Biomass at 50% Flowering and at Harvest showed similar trends in treatment effects; highly significant differences were observed for the effect of Spacing ($P \leq 0.004$), Time of planting ($P \leq 0.001$) and Variety ($P \leq 0.001$). The results for biomass at harvesting also showed consistent differences between treatments, confirming the importance of using the correct spacing and other crop management practices. Similar results were obtained at Chitala Research Station and Mwimba Farm Institute.

In the second season (2009- 2010), significant differences were observed ($P \leq 0.006$ and $P \leq 0.001$) for kernel yield for the different Ridge spacing and the Time of planting treatments, respectively. However, varieties did not show any significant differences ($P \leq 0.05$) in this season. Highest yield (606 kg ha $^{-1}$) was obtained at 75 cm followed by 90 (490 kg ha $^{-1}$), and lastly (341 ha $^{-1}$) at 120 cm row spacing. The highest yield under the Time of planting treatment was realized from the earliest planting (712 kg ha $^{-1}$), while the least yield was from the last date of planting (293 kg ha^{-1}). These findings are consistent with results obtained in previous research work that showed the effects of delayed planting that is sometimes done by farmers because of the late transplanting of tobacco. However, it should be noted that while the treatment effects had a similar trend as in the previous season, the yields were generally very low in the second season (2009-2010). Interestingly, the observations though still confirmed that Ridge spacing and Time of planting are important crop management practices if farmers are to achieve higher yields of groundnut. The results were similar elsewhere including the on-farm sites.

The conclusion we draw form these observations strongly confirm the need to factor time of planting, ridge spacing and varieties for prediction of yield. Therefore, the APSIM Model should always have these factors when simulating the different scenarios. Most importantly, farmers need to consider all these factors in order to get better yield of groundnut.

At the Chitedze Research Station, significant differences were observed ($P \leq 0.006$ and $P \leq 0.001$) for kernel yield for the different Ridge spacing and the Time of planting treatments, respectively. However, varieties did not show any significant differences ($P \leq 0.05$) in this season. Highest yield (606 kg ha $^{-1}$) was obtained at 75 cm followed by 90 (490 kg ha $^{-1}$), and lastly (341 ha $^{-1}$) at 120 cm row spacing. The highest yield under the Time of planting treatment was realized from the earliest planting (712 kg ha $^{-1}$), while the least yield was from the last date of planting (293 kg ha $^{-1}$). These findings are consistent with results obtained in previous research work that showed the effects of delayed planting that is sometimes done by farmers because of the late transplanting of tobacco. However, it should be noted that while the treatment effects had a similar trend as in the previous season, the yields were generally very low in this season (2009-2010 rainy season). Observations still confirmed that ridge spacing and time of planting are important crop management practices if farmers are to achieve higher yields of groundnut.

5.2.3 Climate risk management and market opportunities

The series of on-station trials conducted across the main groundnut producing areas of Malawi were done in order to test the effect of plant population and time of planting on groundnut production for a range of improved and traditional cultivars (Field Trial Report, Activity 3.2). Plant growth and yield of cultivars, and soil and climate conditions of the experiments were monitored intensively to obtain data to calibrate the APSIM-Peanut crop growth model (Activity 3.2). The Malawi Met Services provided appropriate quality-checked long-term climate data for a number of sites where groundnut production is practiced or has potential (Activity 3.3 - 3.5). Met input files for APSIM were then constructed from this data and the calibrated APSIM-Peanut model was used to assess the impact of seasonal rainfall variability interacting with cultivar choice, time of planting, and plant population across the project test sites (Activity 3.6).

Materials and methods and the results of the field experiments were as highlighted above and are detailed in the separate report submitted for Field trials. Here, data from the trials was provided for simulations of the different scenarios. The results of the phenology trial were used to evaluate APSIM's performance in simulating plant population and time of sowing effects on groundnut growth and yield of the 2 cultivars.

The simulation modelling work needed soil data for inputting in the Model. Therefore, soil samples were collected twice from the three on-station trial sites: (a) prior to planting; and (b) at harvest of the first (TOP1) and last (TOP4) sown treatment plots, to a depth of 180cm. Soil layer depths sampled were: 0-10, 10-20, 20-30, 30-60, 60-90, 90-120, 120-150, 150-180cm. The pre-planting soil samples were analyzed for SOC (%) and SON (%) and SOP (%). Soil sampled at groundnut maturity at the time of planting (TOP) trials were analyzed for soil water content (% GM) and converted to % volumetric content using assumed bulk density to reflect the soil texture at each site – average BD across soil layers at Mwimba = 1.54 g cm^{-3}, Chitala = 1.28 g cm^{-3}, and Chitedze = 1.18 g cm^{-3}.

Results of soil chemical analysis were also used to derive soil layer organic carbon contents for input to APSIM and the soil C:N ratio was set to 12:1 for all sites (based on results of Chitala and Chitedze soils, 0-10cm, and no % N data for Mwimba). Soil water parameters for plant lower limit (LL), drained upper limit (DUL) and saturation (SAT) of soil layers were described to give a plant available water holding capacity (0-180cm) of 120mm at Mwimba, 150mm at Chitala, and 175mm at Chitedze.

Climate files for each site were constructed for the period 1 August 2008 - 30 June 2009. First daily rainfall data were collected from 11 October 2007 onward at Chitedze, from 30 October at Chitala, and from 23 November at Mwimba. Daily rainfall amount, for the periods outside that which was measured, was set to zero. Daily maximum and minimum temperature data were available for the duration of the constructed climate record at the

Chitedze site. NASA data were used to fill in missing temperature and radiation data at each site.

Results of the calibrations conducted provided reliable estimates of the phenology parameters for the 5 test cultivars. However, calibration of the biomass and partitioning parameters using the field measured data in this study was compromised by inexplicably high HI's in the observed results. The default maximum HI for groundnut in APSIM is 0.45 and estimates from the ICRISAT groundnut varietal database at Chitedze reveal HI for Spanish types as 0.36-0.40, for Virginia types as 0.22 to 0.32 (seem low), and for Valencia types 0.36-0.45 (Monyo, personal communication). The calibration in this study used 0.55 and 60% of the observed HI's in the phenology experiment were above this value.

Long term simulation results for each of the 3 sites (Chitedze, Chitala and Mwimba) showed that there is little variation in expected yields of CG 7 for sowing dates of November15 to December 13. However, the trend showed that there is a consistent decline (34-40 kg/day) in expected yield for plantings later than December 13. For the late January 17 planting, there was a 49% reduction in yield (from the maximum yield) at Chitala, 37% at Chitedze, and 35% at Kasungu. The shorter duration Kakoma cultivar, at the earlier planting dates of November 15 and November 22, showed yield reductions of 14-20% at Chitedze and Kasungu sites relative to the yields simulated for the optimal planting dates of December 6 and December 13. (This could be due to the unreliability of starting rains and the higher proportion that this period of moisture stress represents in the overall crop duration of the cultivar). In contrast to CG 7, later planting of Kakoma (after the optimal dates) at these two sites had only minimal yield reductions (6-7 kg/day). At the Chitala site, Kakoma displays a similar pattern to CG 7, with a flat yield response to planting dates up to December 13, and a consistent decline in yield (22 kg/day) for plantings later than this date.

The simulation results showed that planting CG 7 later than December 13 results in increasingly longer crop duration implying a trend of increasing levels of moisture stress for the later sown crops. The increased crop duration of Kakoma variety at later plantings was markedly less, suggesting much less moisture stress for this cultivar as compared to CG 7. This result is because of the interaction of crop growth and development rate with the available water capacity of the soil and its supply to the crop. In the case of Kakoma variety planted after December 13, the soil water supply was mostly adequate in buffering crop yield against declining in-crop rainfall up to crop maturity whereas it was mostly inadequate for the longer duration CG 7 which takes an additional 20-30 days to mature, even under non-stress conditions. Therefore, the simulated yields suggest that on average, it is much better to plant CG 7 across all 3 sites than the shorter duration Kakoma and this applies for all sowing dates as well, except for very late planting (January 17) at Chitala. However, the averages masked the underlying variability in yield performance of the two cultivars across the seasons. For example, it was observed that Kakoma yielded higher than CG 7 in 30% of years for a December 27 planting at Chitala. The yield advantage of Kakoma in simulated 9 years averaged 200kg/ha, but did not exceed 500kg/ha. In comparison, the CG 7 average yield advantage in the other 70% of years was 500kg/ha, and was as much as 1300 kg/ha despite the late sowing date. The challenge that this result presents is whether the Kakoma-favoured seasons can be anticipated in some way, for example by use of seasonal forecasting techniques.

Equivalent data across sowing dates confirmed that if grain yield is the farmers' objective, then it would be best to plant CG 7 rather than Kakoma at the 3 sites for all sowing dates except for the very late planting (Jan 17) at Chitala where 60% of years would be favoured by the Kakoma selection. However, the simulated results and varietal comparisons here reflected conditions not commonly found in farmer fields – deep soil with high water holding capacity, recommended row spacing and plant population, no weed competition as well as non-limiting nutrients. The high average yields (all above 1500kg/ha) were indicative of the atypical nature of the results. The shallow soil and sub-optimal plant populations scenario (more in line with smallholder farmer conditions), dramatically reduced the average simulated yields for the various cultivar x site x sowing date scenarios, with yield range of 800-2700 kg/ha. A further noticeable change was that all the treatments then showed a linear yield decline with later planting dates and that the threshold planting date for the decline shifted from December 13 back towards November 29 and December 6. The rate of yield decline for CG 7 was now 26-29 kg/day across the 3 sites (cf. 34 - 40 kg/day above) and for Kakoma it was 11-17 kg/day, reflecting the lower overall potential yields in this scenario. However, yield reductions with late sowings were then much more substantial, with January 17 plantings of CG 7 having 50-59% yield reductions relative to the optimal planting date yields (cf 35-49% above) and Kakoma having 30-45% reductions (cf 14-31% above). With the shallow soil scenario, it was now more often the case that the shorter duration Kakoma was a better cultivar option for later sown crops. At Chitala, the cross-over for selecting Kakoma was now the January 3 plantings and it was January 10 at Kasungu. At Chitedze, even with a shallow soil depth, CG 7 was able to out-perform Kakoma across the range of tested planting dates in the majority of seasons.

6 Project Outputs

The project registered various tangible outputs contributing significantly to the welfare of the farmers in the target sites. Additionally, interaction among project partners, farmers and other stakeholders resulted in enhancing the knowledge base on innovative approaches to crop productivity improvement and climate risk management.

6.1 Direct achievable products of completed activities

The project conducted a number of research activities involving a field survey and a desk study with the aim of studying the disadvantages of tobacco farming. Furthermore, other studies encompassed groundnut field trials with the aim of obtaining information on crop phenology, the data from which could then be used for calibrating the APSIM model for local conditions, (please note that the APSIM model had default parameters based on Australian conditions). Research was also conducted on effects of crop management practices in order to develop data under different scenarios that would be used for simulating groundnut yield under different future scenarios.

Major outputs from the research have been the following reports: 1) A report on the field survey and the desk study; 2) A report on groundnut field trials on crop phenology and effects of agronomic practices (time of planting and row spacing); and 3) A report on crop simulation modelling. Despite being authored by different researchers, all these were submitted by ICRISAT as the lead organization. As such the reports are already with IDRC, having been submitted earlier as progress reports for specific objectives.

The project also concentrated on infrastructure development that involved providing software to the Malawi Meteorological Department. The main output has been the acquisition of MARKSIM software which was used by the Meteorological Department to fill the gaps in the data collected from Chitedze, Chitala and Mwimba Research Stations. This work resulted in the production of a complete set of climate data for the concerned stations covering the previous thirty years to the date of start of the current project. The *major output* is that Malawi now has – for the first time – a full data set on climate and weather parameters for the southern Africa region. Continued use of the software by the

Meteorological Department puts Malawi in a better position to undertake climatic risk assessment and climate change predictions. The field trials conducted with the major groundnut cultivars have concretized the information and knowledge of the effects of crop management practices on groundnut yield as shown by the effects of time of planting, row spacing and varieties. Here, the effects of these factors have been discussed and documented with farmers in the target project sites. The process has enhanced learning by the farmers enabling them to continue benefiting from the knowledge through adaptation and adoption of good practices to their farming situations. However, combining the outputs from the different components of the project with relevant socio-economic parameters (using GIS) to determine targeted recommendation domains for legume diversification strategies could not be done due to time and financial resource limitations as this required data from the rest of the activities.

6.2 Capacity building

The project worked strenuously to build the capacity of the local meteorological department in Malawi by training one staff member (Fred Kossam) on climatic data handling with MARKSIM, thereby increasing the capacity of the department to handle climatic data that has gaps in future. This training was provided by Reading University through the expertise of Dr. Rodger Stern who provided the overall backstopping on weather data management. An ICRISAT research technician, Emmanuel Mkuwamba was sent to ICRISAT Zimbabwe to learn data management for the field trials with mentoring by Dr. John Dimes, and this training helped the technician to ably handle all the data generated for the crop simulation activities. The increased institutional capacity is sustainable in the sense that the trained people will continue working on similar research activities and further build the capacity in the country by continued collaboration and partnerships as they also act as trainers of trainers. The partnerships formed between research institutions (ICRISAT, Malawi Meteorological Department, IDRC, University of Reading, Department of Agricultural Research Services) are sustainable in the sense that there can be continued interaction and joint efforts whenever the need arises. These relationships would not have come about without IDRC's funding of the project.

6.3 Influence on policy and social change in farmer practices

The project was exploratory in nature – it first aimed at identifying the disadvantages of tobacco farming while at the same time determining the potential of groundnut to take the place of tobacco in terms of cash generation for small-scale farmers. Generally, farmers adopt technologies slowly as they learn and realize the benefits of changing their ways of doing business. But remarkably, within the short span of two years, which was the duration of the project, farmers benefited from the various project activities and changed their habitual practices. So surely, the farmers who were direct participants of this project saw the advantages of timely planting of groundnut with appropriate plant population and will practise groundnut farming differently after the experience, as all farmers are basically interested in getting better yields.

From the difficulties experienced in getting full data sets from satellite weather stations, the Meteorological Department must have changed their data recording and maintenance methods so as to avoid repeating the previous errors that led to such incomplete data sets. It is therefore anticipated that meteorological stations would now be closely monitored in the way climate data is recorded, handled and maintained. Knowledge has now been created and skills imparted, and there should be no excuse in future for scant climatic data from the satellite meteorological stations in Malawi.

7 Project Outcomes

One of the better scientific and research outcomes has been the calibration of the APSIM model which has been adapted to the local conditions and can be used to simulate groundnut yield for Malawi. However, the lack of correlation between the biomass and the grain yield requires further studies as it was observed to have resulted in higher HI than expected, which in turn led to poor prediction of the grain yield. The knowledge innovation the project imparted to the Meteorological Department is yet another major outcome as a result of the project activities on climate risk assessment and prediction. The generally improved understanding of the production analysis and economic analysis of crop enterprises was brought about by the integration of crop simulation modelling as a decision tool using groundnut as a case study, and it has created confidence in the implementing partners to undertake research projects on climate change risk mitigation through crop diversification.

7.1 Behaviour changes among researchers, research users, networks

The project only had a two-year lifespan. Therefore, changes are yet to show up beyond the project lifespan when we expect farmers to change cropping systems, patterns and practices. There is always a time lag for learning to be effective and to start showing observable tendencies.

Similarly, technologies developed through research have developmental and adaptive phases, and then the adoption phase starts as farmers build up the necessary confidence to implement then, having observed and realized reasonable benefits. All this cannot be achieved in two years. The achievement though has been the documentation of the effects of tobacco from the livelihood, health and environmental perspectives from which learning and adoption of the strategies will be based so as to avert the deleterious effects of tobacco farming. Deliberate policies that seek to create awareness of the dangers of tobacco farming and suitable options for diversification out of tobacco need to be clearly formulated. Anti-tobacco campaigns need to be put into national policy through advocacy and lobbying of policy makers. Tobacco prices have stagnated and continue to show a rapidly declining trend in Malawi and globally, calling for governments to change their policies on tobacco by choosing new crop mixes that present more beneficial than harmful effects (as has been shown in the case of tobacco). A difficult period appears to be looming on the horizon for Malawi as the incorporation of anti-tobacco campaigns into the national policy through recommendations by government will continue to face opposition in the absence of proven alternatives to tobacco farming. However, the study on groundnut has shown high potential as an interim alternative crop enterprise since most households interviewed in this research project already grow both tobacco and groundnut, but greater publicity needs to be generated on the beneficial attributes of groundnut farming so as to outweigh the cash benefits offered by tobacco. However, one comforting fact is that only a small proportion of the tobacco produced in Malawi is consumed locally, mainly by a small segment of the population that is exposed to smoking.

7.2 Lessons learned on approaches, design elements and changes in orientation for conducting research

During project implementation, NASFAM used 'intention' given on the farmer registration forms to identify tobacco farmers (those who viewed tobacco as being the major cash earner for the household and declared as such upon registration with the association) or groundnut farmers (those who registered with the view that groundnut was the major cash earner for their household and registered as such). This led to confusion in the survey methodology as NASFAM interviewed farmers as either tobacco or groundnut farmers. In reality farmers grew both groundnut and tobacco but chose to register only under one of the crops based on intent and anticipated services that they could avail of from registering under either one of the two crops. This was, therefore, the reason why the sampling of farmers eventually revealed that the farmers designated as tobacco farmers also grew groundnut and vice versa. This led to complications in determining the differences between tobacco farmers and groundnut farmers since in essence both farmer categories were found growing both crops, and therefore must have registered the cost of production and even sources of income. Therefore, it has not been properly established in the results as to which farmer group is better off than the other, information which could have helped us compare the livelihood domains of both tobacco and groundnut farmers.

In the course of project implementation, we learnt that capacity building was a successful way of conducting research. At the beginning, the Meteorological Department had no capacity to undertake gap-filling of the climate data. After training the officers were able to fill in the gaps in the missing climatic data using the MARKSIM software. The research technician attached to the field and crop modelling trials was able to collect and handle a large and complicated data set from the field trials upon exposure to the application requirements of the APSIM crop model.

The project had built-in planning meetings held annually and attended by all the project partners and stakeholders. Project scientists shared experiences and also obtained input from outsiders through presentations that preceded annual planning sessions to review progress and compile the annual work plans for implementation in the subsequent year. The lessons drawn from this approach were that project review meetings with outsiders allowed for exchange of ideas and enriched the project implementation plan. With proper planning, the activities proceeded with a minimum of bottlenecks towards achieving the set target outputs.

8 Overall Assessment and Recommendations

The partnership approach to project implementation was valuable for the achievement of the project objectives. As a result of using the partnership approach, the project benefited from the diverse expertise offered by partners in various disciplines who had sincere dedication towards implementation and achievement of the project objectives. The project team had agronomists, modellers, statisticians, socio-economists and meteorologists. The Canadian experts also provided useful inputs on the direction of the research and provided financial support. This facilitated timely achievement of results as time was not wasted in brain storming and soul searching regarding methods through which certain objectives could be achieved.

To IDRC, we recommend that in future, projects of this nature should be given more than one phase so as to allow meaningful technology development, with definite adaptation and adoption phases so that the real output can be measured. IDRC should also encourage information sharing across projects so that new projects benefit from the old projects, thereby allowing for learning to take place between projects so as to reduce the negative effects of implementation constraints and to enhance the project's success. This should not only be done at project closing workshops, but right from inception and intermittently through the implementation period. There is need also to match funding levels (amount) to project activities while remaining flexible and responsive to externalities so that no activities suffer from implementation hiccups as a result of inadequate financial resources. The current project required soil analysis but as it was deemed to be an expensive exercise in terms of time and financial commitment it could not be undertaken, and also because it had not been included in the project proposal.

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