Integrated resource management in crop-livestock farming systems of sub-Saharan Africa

A research proposal from the Soil, Water and Nutrient Management Program of the CGIAR

Submitted to: **The Department for International Development DFID-UK**

By: **International Center for Tropical Agriculture CIAT - Colombia**

December, 2000

1. Project Summary

Title:

Integrated resource management in crop-livestock systems of smallholder farmers in sub-Saharan Africa

IARC: Centro Internacional de Agricultura Tropical

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Total cost of project (UK £): 421,620

Duration of project: 3 years

Date of submission: December, 2000

Location of project: East and Southern Africa

2. Background

In order to meet the increasing demand for food associated with population growth and dietary changes, livestock will play an increasingly significant role in the production systems of farmers in developing countries (Delgado *et al.*, 1999). Crop and livestock production must therefore each expand by more than 3% annually to keep pace with this increased food demand (Ousmane Badiane and Delgado, 1995; Winrock International, 1992). Such pressures are forcing the integration of separate crop and livestock production systems and the intensification of existing mixed farming systems (McIntire *et al*., 1992; Winrock International, 1992).

All land on the African sub-continent which is classified as very suitable for cultivation is already under cultivation (F.A.O., 1986). Farmers are intensifying their agricultural production by utilising marginal lands and converting communal grazing lands to arable land. Recent evidence

suggests that in these systems soil degradation is occurring extensively, threatening the resource base for continued plant and animal production (Scherr, 1999; WRI, 2000). In addition concern has been expressed over the possible negative effects of increased animal production on the quality of the environment, e.g through the absence or mis-use of improved technologies that may result in pasture degradation through overgrazing. The role of more intensive livestock production systems, whereby nutrients from low quality sources are captured and concentrated into higher quality manures, is particularly important in farming systems where nutrient depletion is occurring at alarming rates (e.g., Stoorvogel and Smaling 1990).

Much effort has been made with respect to the questions of the sustainability of these systems in terms of, for example, improved pastures and optimal stocking rates but often with little attention paid to the effects of manures and crop residues on soil processes, the maintenance of soil fertility and prevention of soil degradation (Powell *et al.*, 1995). There is a need then to focus not only on increasing animal production, *per se*, but also on improving the integration of livestock and livestock products into production systems to ensure maximum use of their benefits while minimising their detrimental effects on the environment (de Haan *et al.*, 1997). These beneficial effects include the more efficient utilisation of animal manures, crop residues and forages that can often be the only source of nutrient inputs for farmers who cannot afford to purchase fertiliser and other inputs. Legumes hold the key in this crop-livestock intensification, improved fallows and cover crops can increase soil fertility, suppress weed species and provide fuelwood, dual purpose legumes can also be used for livestock feed, which in turn increase the quality of the manure produced. In addition the niche that legumes can occupy in the farming system, for instance, fodder banks on soil conservation bunds, provides multiple benefits to the farming system.

Resource-poor farmers face difficult decisions over the use of scarce nutrient sources in crop-livestock production systems. Often the decisions taken on the use of animal products are taken without an assessment or appreciation of the impact of the potential of different uses on plant production and on soil and water resources. A deeper understanding of the comparative values and usefulness of manures and other locally available resources is required in order to increase the production and efficiency of mixed crop-livestock systems. While efforts are required to expand our knowledge of the biophysical aspects of alternative uses of organic nutrient sources similar efforts are also required on the socio-economic driving forces behind farmers' decision making. The project will utilise trade-off analysis and partial budgeting of new technologies to identify and introduce new crop-livestock technologies.

Figure 1 shows schematically how the project will contribute to farmer decision making with respect to the better use of available resources and hence improved food and livelihood security. The project aims to bring together farmer understanding of available resources including trade-offs with respect to soil fertility and livestock with researcher understanding of soil processes, ruminant nutrition and long-term nutrient balances.

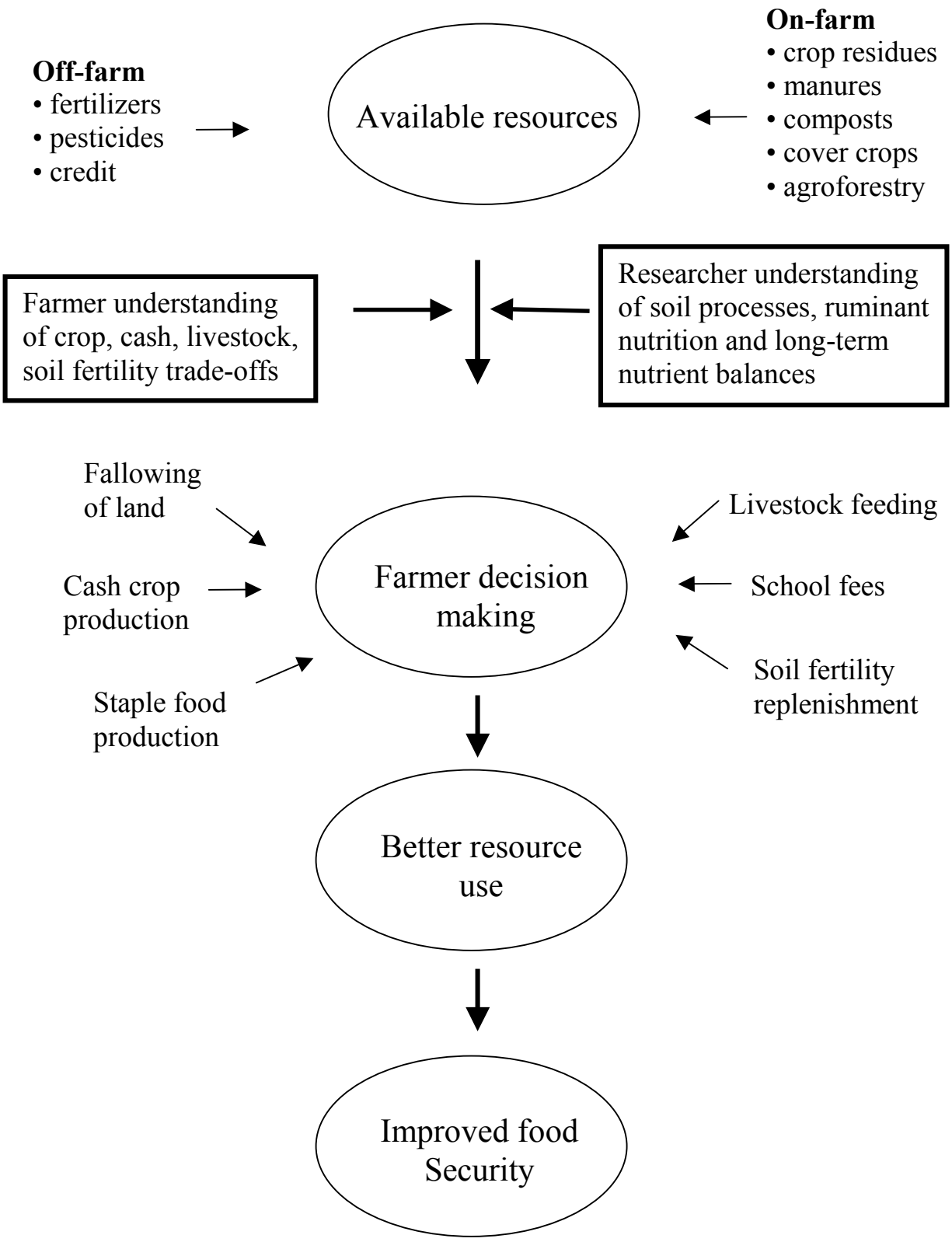

Figure 1. Schematic representation of the project

3. Justification:

The challenge of future intensification was clearly summarised by Nywe (1992), "strategies for ensuring adequate nutrition of ruminants must be based on optimising overall agricultural and livestock productivity from available resources, improving existing technologies and integrating technology that employs multipurpose crops and animals and recycling of crop residues and by-products as nutrients for both animals and plants".

Despite the considerable work on nutrient flows in crop-livestock systems our knowledge of them remains fragmentary and imprecise making the development of economically, socially and environmentally acceptable guidelines difficult (Swift *et al.,* 1989, Powell *et al.*, 1995). Effort is required to manage nutrient flows for more efficient production of marketable goods (meat, milk and crops) coupled with better soil and water management in terms of reducing degradative processes such as erosion and nutrient depletion.

Included in this range of options for the improved utilisation of nutrient sources is the management of feed resources for animals, the use of animal manures and the subsequent value of manures for soil and improved crop productivity. Forage legumes, for example, have varying compositional qualities, mainly associated with nitrogen, lignin, polyphenol or tannin contents, that significantly effect the intake of nutrients by animals, the partitioning of nutrients between faeces and urine and the quality of the manure. In addition the composition of forage residues and litter is a regulating factor in the decomposition and release of nutrients when returned to the soil (Swift *et al.,* 1979, Palm *et al.,* 2000) thereby affecting nutrient cycling in the soil-plant-animal system.

This project will synthesise existing but uncollated information, answer key research questions through strategic and adaptive research and develop user-friendly guidelines that can be used by extension groups and farmers. This effort requires a broad multi-disciplinary approach that has been lacking in the past (SWNM 1999). For this reason the project will bring together expertise from two CGIAR Systemwide projects namely the Soil, Water and Nutrient Management Program (SWNM) and the Systemwide Livestock Program (SLP).

4. Project goal:

To improve food security, increase incomes of smallholder farmers and conserve the soil resource base through improved resource management in crop-livestock production systems

This goal will contribute to DFID's RNRR purpose statement "benefits to poor people generated by application of new knowledge to natural resource systems".

5. Project purpose:

To increase the productivity and profitability of smallholder farms through the use of decision support tools for the improved use of forage legumes, animal manures and other organic resources for better integration of crop-livestock systems

This purpose will contribute to DFID's RNRR strategy output 1, relevant new knowledge created, output 2, use of knowledge promoted and output 3 knowledge disseminated.

6. Research Activities:

Output 1: Model(s) for assessing alternative uses and management of forage legumes and animal manures in crop-livestock farming systems developed and evaluated

Activities:
1.1 Collection, collation and evaluation of information, databases and models relating to potential nutrient use efficiencies of crop-livestock farming systems.
1.2 Standardisation of datasets and outputs for testing of models.
1.3 Hypothesis and scenario testing of trade-offs between competing and synergistic utilisation of organic inputs in crop-livestock systems.
1.4 Development of a virtual laboratory for exchange of information, data, models and results amongst stakeholders

Output 2: A decision support tool for evaluating alternative nutrient sources, management of those nutrients and impacts on soil fertility and livestock production developed and evaluated.

Activities:
2.1 Field evaluation and verification of promising model predictions for integrated crop-soil-livestock production systems through multi-locational standardised network experiments
2.2 Testing and development of prototype DS tool on-farm in East and Southern Africa by project partners (NARES, NGO's, IARC's, farmers)
2.3 Revision of prototype and testing over a wider range of sites including West Africa.

Output 3: Decision support tool disseminated in a range of formats, including extension manual, researcher decision support system, to different stakeholders

Activities:
3.1. Development of user-friendly versions of the decision support tool with different stakeholder groups (farmers, NGO's etc)
3.2. Hold a series of training events with stakeholders to demonstrate the decision tools
3.3. Development of criteria and baseline survey for future impact monitoring
3.4 Dissemination of DS tool through conference papers, journal articles and the internet

Research strategy:

The target groups of the project are;
i) Smallholder farmers integrating crop and livestock production systems
ii) NARES staff working on crop-livestock systems
iii) Researchers investigating integrated nutrient management technologies and policies iv) Policy makers concerned with regional and country level nutrient depletion, crop-livestock production, rural livelihoods and food security

The target agroecosystems are the sub-humid East African Highlands and Southern Africa semi-arid zones characterised by high population densities and presence of mixed crop-livestock farming systems. Linkages will also be established through the SLP with similar zones in West Africa.

The research strategy involves,

i) a synthesis workshop of existing information on the interactions between animals and soil, soil fertility and erosion
ii) comparisons of the available models on plant-animal-soil interactions and
iii) the development of a user friendly decision tool that will enable farmers to choose the most efficient option for the use of both animal and plant organic materials for soil fertility improvement

7. Contribution from existing projects in the target region:

Considerable information exists on crop-livestock farming systems in East and Southern Africa, yet predictions and recommendation are difficult due to the variable nature of biological processes and the trade-offs between uses of organic inputs in the farming system. Linking these data with models that simulate livestock productivity, manure quality, nutrient release patterns, soil organic matter dynamics, and crop response could provide a means of making initial recommendations for testing with farmers. Refinement of these recommendations will allow the development of a DS tool that will improve the management of crop-livestock systems, improve rural livelihoods and increase household food security.

Much research has been conducted in East and Southern Africa by ILRI and TSBF and a wide range of national partners in mixed crop-livestock farming systems (Murwira *et al.*, 1995; Powell and Williams, 1995; Mugwira and Murwira, 1997; Fischler and Wortmann, submitted; Delve *et al*., 2000a). ILRI and ICRISAT and their partners (Powell & Williams 1995) have conducted comparable work in West Africa. Much of this work has led to the development of recommendations and decision guides for the best bet use of green manures (Fishler and Wortmann, submitted; Palm *et al.,* 2000), feeding of crop residues to livestock (Methu, 1999) and for manure management (Lekasi, *et al.*, 1998; Nzuma and Murwira, 2000). In addition, key reviews have been conducted through the African Highlands Ecoregional Programme (AHI) on the use of legume cover crops (Gachene *et al.,* 1999) and the use and management of animal manures (Kihanda and Githuru, 2000). This project will collate and integrate these and other information sources from the many projects in the East and Southern African region. The resulting database of research results will be utilised for model development and testing and contribute to the design of the improved Decision Support (DS) tool proposed in this project.

This project will also build on on-going work in the target regions. The current DFID funded SWNM project has successfully developed an Organic Resource Database (Palm *et al.*, 2000; Delve *et al.*, 2000b) and tested a N management decision tree which has been developed by TSBF and collaborators (through Confronting Soil Erosion and Nutrient Depletion in the Humid/sub-humid Tropics project). The existing Organic Resource Database (ORD) will form an integral part of the modelling effort allowing data from many sources to be synthesised and incorporated in to the modelling work (Palm *et al.*, 2000). Linking the ORD, the N management decision tree with the decision tree for manure management and use developed in Southern

Africa will form the basis of the DS tool, co-funding through the DFID, IFAD and Rockefeller project in Southern Africa will allow for field testing of the new DS tool.

Another current SWNM project on 'Integrated Nutrient Management in Tropical Cropping Systems: Improved Capabilities in Modelling and Recommendations' funded through ACIAR aims to adapt the Agricultural Systems Simulation Model (APSIM) model for tropical soils and cropping systems, including the use of organic inputs and animal manures in soil fertility management. In conjunction with a second project, funded through Rockefeller, based at the Kenya Agricultural Research Institute on 'integrated use and effects of manures on modest application of inorganic fertilisers on soil properties and maize production in the central Kenya Highlands' they will specifically evaluate and adapt the APSIM MANURE and ORGANIC MATTER modules to allow prediction of nitrogen availability, soil organic matter and crop production for a broad range of organic inputs (including manures) and their combination with mineral fertilisers.

The development and dissemination of the outputs will be done in close collaboration with the African Highlands Initiative (AHI) and the CGIAR Participatory Research and Gender Analysis (PRGA) Systemwide program, building on the experiences gained through their participatory approaches to ensure that uptake pathways for the project products are clearly defined, delivered and monitored. The AHI and the NRM group of the PRGA program will be key vehicles for refinement, testing, dissemination and scaling out of developed approaches with and to other scientists working on multi-purpose legumes and crop-livestock intensification.

Collaboration between the SWNM and the Systemwide Livestock Program (SLP) is already on-going in the area of nutrient cycling and manure quality using the APSIM model. In addition, the SLP are developing a complementary project on improving feed quantity and quality and especially on the role of forage legumes in determining nutrient intake by different animals (e.g. cattle, sheep goats and chickens) and subsequent effects on the quality of excreted products. This SWNM proposal will explicitly link these two projects to optimise the added value from co-ordinating these projects. Linking the ORD and the SLP forage databases and the ruminant and soil modelling work using APSIM will further increase our capacity to simulate crop-livestock production systems and allow extrapolation of process research from the plot to the farm scale.

In addition, the following SLP projects will also provide useful input for this proposed project, these projects are:

1. Utilisation of forage legume biodiversity for dairy production and natural resource management in East and Central Africa
2. The maize crop as food, fodder and fertiliser in intensifying crop-livestock systems in East and Southern Africa
3. Ex-ante impact assessment of maize as food, fodder and fertiliser in intensifying crop-livestock systems in East and Southern Africa
4. The role of agroforestry and livestock strategies in building assets and improving livelihoods: learning from successes to catalyse sustainable intensification of smallholder agriculture in the East African Highlands

8. Beneficiaries:

The direct beneficiaries of this program are the smallholder crop-livestock farmers of the sub-humid zones of East and the semi-arid zones of Southern Africa. The project aims to directly impact on increased efficiency of production and lessened production risks that will enhance farmer livelihoods and food security. In addition, researchers, NARES and extension workers will benefit from the user-friendly decision support system and the associated training. Policy makers will also benefit from access to the decision tool as a component of wider policy considerations on nutrient depletion and replenishment in African countries. The indirect beneficiaries are the smallholder farmers in similar production systems who will benefit from the refinement of crop-livestock farming practices as the results of this programme become disseminated through the other activities of the collaborating stakeholders.

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Logical Framework Matrix

Narrative summary	Objectively verifiable indicators	Means of verification	Important assumptions
Program goal To improve food security, increase incomes of smallholder farmers and conserve the soil resource base through improved resource management in crop-livestock production systems	Food security improved and farm income increased in target areas	Household income and yield data from the farm enterprise	Farmers participate in the project, farmers provide household and other data
Project purpose To increase the productivity and profitability of smallholder farms through the use of decision support tools for the improved use of organic resources, forage legumes and animal manures.	A decision support tool completed from collated information and new research results.	Decision support tool software and training materials produced. Training and policy workshops. Publications.	Data is available for decision support tool development
Outputs 1: A model for assessing alternative uses and management of forage legumes and animal manures in crop-livestock farming systems developed and evaluated 2: A decision support tool for evaluating alternative nutrient sources, management practices and impacts on soil fertility developed and evaluated. 3: DS tool disseminated in a range of formats to different stakeholders	A crop-livestock model developed and tested A decision support tool developed and tested Decision support tool developed for different stakeholders. Workshops held	Computer based model Computer and booklet based decision support tool Workshop reports Publications	Organizations will collaborate to harmonise methods Organisations will collaborate to harmonise methods Decision support tool can be produced in booklet form
Inputs Full-time research Scientist, joint appointment between by TSBF and CIAT. Proportion of time of 5 senior scientists from CIAT, TSBF, ILRI and APSRU	Research scientist appointed	Contract of appointment Annual reports from collaborating institutions	Suitable candidate can be found

Fig 1. Work breakdown structure

Project Goal
To improve food security and increase incomes of smallholder farmers with crop-livestock production systems

Project Purpose
To increase the productivity and profitability of smallholder farms through the use of decision support tools for the improved use of organic resources, forage legumes and animal manures

Output 1	**Output 2**	**Output 3**
A model for assessing alternative uses and management of forage legumes and animal manures in crop-livestock farming systems developed and evaluated	A decision support tool for evaluating alternative nutrient sources, management practices and impacts on soil fertility developed and evaluated	Decision support tool disseminated in a range of formats to different stakeholders
Activities: 1.1 Collection and evaluation of information, databases and models relating to potential nutrient use efficiencies of livestock-arable farming systems 1.2 Standardisation of datasets and outputs for testing of models. 1.3 Hypothesis and scenario testing of trade-offs between utilisation of organic inputs for crops and livestock. 1.4 Development of a virtual laboratory for exchange of information, data, models and results amongst stakeholders	**Activities:** 2.1 Field evaluation and verification of promising model scenarios outputs through multi-locational standardised network experiments 2.2 Test and develop prototype TSBF DS tool on-farm in East and Southern Africa 2.3 Revise prototype and begin testing over a wider range of sites including West Africa	**Activities:** 3.1 Develop user-friendly versions of the decision support tool with NGO's, farmers etc 3.2 Hold a series of training events with stakeholders to demonstrate the decision tools 3.3 Develop the criteria and baseline survey for future impact monitoring 3.4 DS tool disseminated through conference papers, journal articles and the internet