Multiobjective optimization of the trade-offs in smallholder dairy farming intensification

W.M. Mulinge[a,b], W. Oluoch-Kosura[b], S. Staal[c] and S. Mbogoh[b]

[a]Kenya Agricultural Research Institute, P.O. Box 57811, Nairobi, Kenya

[b]University of Nairobi, Department of Agricultural Economics, P.O. Box 29053, Nairobi, Kenya

[c]International Livestock Research Institute, P.O. Box 30709, Nairobi, Kenya

Abstract

As farm sizes decline due to population pressure in the central highlands, smallholder farmers find it difficult to intensify dairying due to competition for resources by alternative crop and other enterprise. However, very little is known the nature of trade-offs the smallholder farmers experience in making decisions about the alternative choices of enterprises and synergy levels available for smallholder farmers. The purpose of this study was to develop and evaluate a framework for guiding choices on alternative agricultural enterprises and enterprise mixes in order to enable farmers to make more informed intensification strategies under varying market access and resource availability. The mathematical model of the decision problem is formulated in terms of multi-objective programming.

It is shown that crops are not likely to replace dairy income, at least in the near term, as farm sizes decline if market access for dairy enterprise is assured. The findings indicate various strategies for smallholder farmers with small land holdings such as land-augmenting (off-farm feed resources, more intensive cropping and dairy enterprises, and continuous as well as mixed cropping). Smallholder farmers with larger land holding can engage in more labour intensive and profitable dairy production technologies. Secondly, profitable crop enterprises, especially in relatively large holdings, and relatively small amounts of labour allocated to fodder production seemed to be critical factors associated with low dairy productivity. A self-help insurance scheme is recommended to increase adoption of intensive dairy systems.

Introduction

- Low Smallholder Dairy Productivity and declining Resource Base (Both Quantity and Quality) with Increasing Demand For Milk
- Need to Intensify Small Holder Crop/Dairy Production Systems
- How to Intensify Smallholder Dairy Production?
- Choice Problem in Allocating Resources between often Competing Enterprises
- Involves Farmers' often Conflicting Multiple Objectives
- The overall objective of this study was to develop an economic model that can be used in assessing the resource use trade-offs that smallholder farmers experience in intensifying dairy production.
- Main Thrust is to focus on the efficient integration of crop and livestock enterprises

Model Formulation

The decision problem was formulated as a multi-objective optimization model defined as follows:

$$\text{Maximise} \quad (f_1(x), f_2(x), \ldots\ldots, f_m(x))$$

$$\text{Subject to} \quad x \in X \subset R^n$$

$$g_j(x) \le 0, \quad j = 1 \ldots\ldots .k$$

where f_i(i=1,……,m): R^n are called objective functions (mainly risk and return formulation) and g_j(j=1, ……., k): $R^n \rightarrow R$ are called constraint functions.

$X_0 = \{x \in X : g_j(x) \le 0, \quad j = 1, \ldots\ldots \ldots k\}$

The feasible set is defined to be

Each point x $\in X_0$ is called a feasible solution.

Solving the Multi-objective Model

•Solving multi-objective models is NOT standard practice (yet).

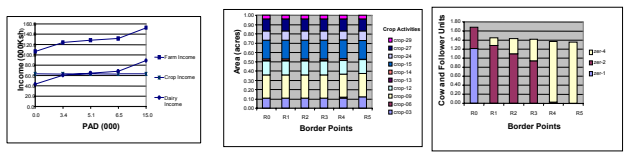
•The first step in solving these models was to *transform* it into a model that CAN be solved using an existing algorithm/solver.

•The Model was converted into a:

- •multi-objective Goal Programming (GP) problem.

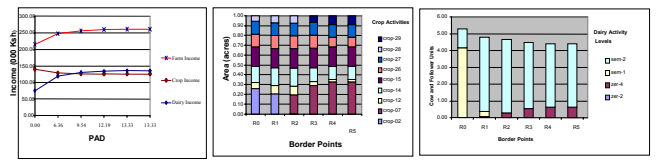
Results

Figure 1 Efficient set Mean Return PAD and Activity levels for 1.8 acres Farm in Kiambu Coffee Zone



Risk Return Trade-off Systems | Selected Crops | Selected Dairy Feeding

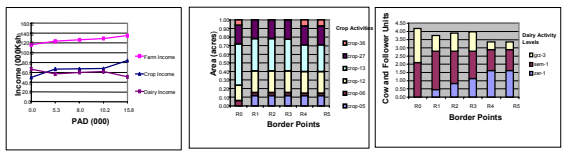
Figure 2 Efficient Set Mean Return PAD and Activity levels for 8 Acres Farm in Kiambu Coffee Zone



Risk Return Trade-off | Selected Crops | Selected Dairy Feeding Systems

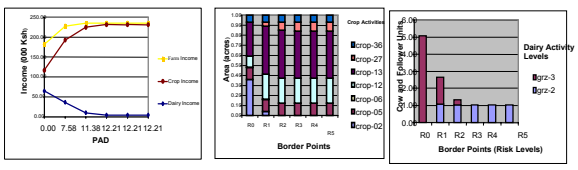
Results Cont-

Figure 3 Efficient Set Mean Return PAD and Activity levels for 1.8 Acre Farm in Nakuru Zone



Risk Return Trade-off Feeding Systems | Selected Crops | Selected Dairy

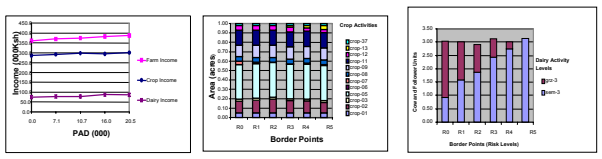
Figure 4 Efficient Set Mean Return PAD and Activity levels for 10 Acre Farm in Nakuru



Risk Return Trade-off Systems | Selected Crops | Selected Dairy Feeding

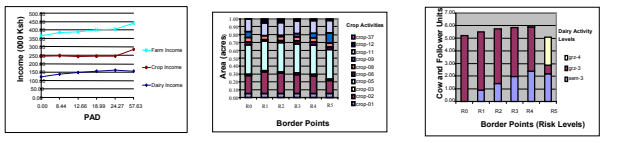
Results Cont-

Figure 5 Efficient Set Mean Return PAD and Activity levels for 10 Acre Farm in Nyandarua Zone



Risk Return Trade-off Systems | Selected Crops | Selected Dairy Feeding

Figure 6 Efficient Set Mean Return PAD and Activity levels for 20 Acre Farm in Nyandarua Zone



Risk Return Trade-off | Selected Crops | Selected Dairy Feeding Systems

Table 1 Crop Activity Codes

Code	Coffee Zone	Horticultural Zone	Nakuru	Nyandarua
Crop-01	Napier grass	Napier grass	Maize	Napier
Crop-02	Coffee	Maize	Napier	Maize
Crop-03	Maize	Grass	Grass	Grass
Crop-04	Grass	Kale	Kale	Kale
Crop-05	Kale	Sweet Potatoes	Sweet Potato	Potato
Crop-06	Coffee-Banana	Maize-Beans	Potato	Beans
Crop-07	Coffee-Napier	Maize-Napier grass	Wheat	Pyrethrum
Crop-08	Coffee -Maize	Maize-Sweet Potatoes	Green Maize	Peas
Crop-09	Coffee-Potato-Beans	Maize-Beans-Potatoes	Onion	Cabbage
Crop-10	Maize-Beans	Napier-Kale	Cabbage	Carrots
Crop-11	Coffee-banana-Potato	Maize-Napier-Beans-Potatoes	Beans	Green Maize
Crop-12	Coffee- Beans	Maize-Napier-Beans-Potatoes-Bananas	Oranges	Maize-Beans
Crop-13	Banana-Maize	Maize-Potatoes	Maize-Beans	Maize-Peas
Crop-14	Coffee-Potato	Maize-Bananas	Maize-Sorghum	Maize-Napier
Crop-15	Maize-Beans-Banana	Maize-Kale	Maize-Sweet Potato	Maize-Sweet Potato
Crop-16	Coffee-Beans-Banana	Maize-Napier-Potatoes	Maize-Beans-Potato	Maize-Beans-Potato
Crop-17	Napier grass-Banana	Napier-Kale-Beans-Potatoes	Maize-Beans-Potatoes-Sorghum-Sweet-Potatoes	Napier-Kale
Crop-18	Maize-Beans-Banana-Napier-Arrow Roots	Maize-Kale-Potatoes	Maize-Napier-Beans-Potato	Maize-Napier-Beans-Potato
Crop-19	Maize-Beans-Napier-Kale-Potato	Napier-Kale-Beans	Maize-Napier-Beans	Maize-Napier-Beans
Crop-20	Coffee-Beans-Napier-Kale	Maize-Napier-Beans	Maize-Napier-Potatoes-Cabbage-Kale-Tomatoes	Potato-Banana
Crop-21	Coffee-Napier-Bananas	Kale-Beans	Maize-Potato-Sugar Cane	Maize-Potato
Crop-22	Napier-Kale	Kale-Sweet Potatoes	Maize-Banana	Maize-Banana
Crop-23	Maize-Bananas-Potatoes	Maize-Napier-Beans-Potatoes-Kale	Maize-Kale-Columbus grass	Maize-Kale
Crop-24	Coffee-Napier-Kale	Bananas-Sugarcane	Maize-Beans-Potato-Kale-Columbus Grass	Maize-Napier-Potato
Crop-27	Coffee-Beans-Napier	Napier-Potatoes	Oranges-Bananas-Maize-Carrots	Napier-Kale-Beans
Crop-28	Maize-Napier-Beans-Potatoes	Maize-Flowers	Maize-Napier-Beans	Maize-Napier-Beans

Table 2 Dairy Feeding Systems

Dairy Producti System	Annual Milk Production (Kg)		
	Maximum o n	Most Likely	Minimum
ZER-1	1778	1595	1422
ZER-2	3225	2743	2224
ZER-3	3285	2920	2255
ZER-4	5480	3655	2000
SEM-1	913	821	730
SEM-2	2378	1086	700
SEM-3	3615	3285	2520

Process of Selecting Strategy

- Alternatives are Generated
  - Information on the Costs and returns of each alternative
  - Select the Best Based on Farm Type and Farmer Risk Aversion Preferences
  - Discard the Inappropriate
  - Sustain the potential alternatives
  - Provide Decision Makers with Guidance in their Selection
- Always Consider
  - Opportunities
  - Objectives
  - Constraints

Conclusions and Recommendations

- **Conclusions**
  - **Modelling crop-livestock integration poses a great challenge**
  - **The multiple objective model is an ideal modelling approach**
  - Smallholder farmers in all the zones experienced considerable tradeoffs
    - between returns/farm income and risk
    - between risk levels
    - Feeding Systems
    - high-risk tolerance versus risk neutral farmers
    - cropping activities
- **Recommendations**
  - **Diversification of smallholder farm portfolio enterprises to reduce the overall risk borne by the Smallholder dairy farmers**
  - **Organise a self-help group insurance scheme to enhance productivity**
  - **Improve infrastructure to increase market access**