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

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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 Threat is to focus on the efficient integration of crop and livestock enterprises

Results

Model Formulation

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

\[
\begin{align*}
\text{Maximize} & \quad f_i(\mathbf{x}) \quad (i = 1, \ldots, m) \\
\text{Subject} & \quad x \in X \\
\text{where } & \quad x \in \mathbb{R^n} \quad \text{and } \quad f_i(x) \leq 0, \quad j = 1, \ldots, k \\
\text{called constraint functions.} & \\
\end{align*}
\]

Each point \( \mathbf{x} \in \mathcal{X} \) is called a feasible solution.

Conclusions and Recommendations

- Conclusions
  - Multi-objective model is an ideal modelling approach
  - Smallholder farmers in all the zones experienced considerable trade-offs
  - 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

Process of Selecting Strategy

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