Effect of management decisions on farm and household outcomes in an integrated crop-livestock agro-ecosystem in Yucatán, Mexico.

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Introduction

Mixed farming systems are defined by Sere and Steinfeld (1996) as those in which more than 10% of the dry matter fed to livestock comes from crop by-products or stubble, and more than 10% of the value of production comes from non-livestock activities. More simply, they are systems where livestock rearing and crop cultivation are, to a greater or lesser extent, integrated components of one farming system. The more integrated systems are characterized by interdependency between crop and livestock activity, optimizing circulation of locally available nutrients. The less integrated systems are those in which crop and livestock activities make use of, but do not rely on each other. Mixed farming systems are extremely important in developing countries. They produce the largest share of total meat (54%) and milk (90%) and are the main system for smallholder farmers in many developing countries (Thornton & Herrero, 2001); indeed two thirds of poor livestock producers rely on mixed crop-livestock systems for their livelihoods (ILRI, 2000).

The need for modeling
• There is a general lack of knowledge of what actually goes on in these complex smallholder mixed systems.
• "Modeling realistically offers the only way of identifying and quantifying the subtle but highly significant interactions that occur between the various components of smallholders' systems" (Thornton & Herrero, 2001).
• Modeling is simply a way of integrating information in a rational way.

Objectives
• Develop a crop-livestock model to assess the biophysical and economic consequences of farming practices evident in Yucatán mixed systems.
• Link the biophysical system to the management system, and determine the consequences for labor needs and economic outcomes.

Agriculture in Yucatán
The traditional agricultural practice of the Yucatán Peninsula, Mexico, is a form of shifting cultivation, known locally as *milpa*. A two to three year cultivation period is followed by a ten to twenty year period of forest fallow. Livestock ownership, including horses, cattle, hogs, fowl, and bees, has long been a part of traditional agriculture. Ownership of hair sheep is a more recent practice, but is becoming increasingly common, due to strong demand for mutton in Mexico City. For smallholder farmers this presents a development opportunity, with potential to diversify income and access potential complementarities between cropping and livestock.

Methods

The Integrated model
An overview of the integrated model is shown in Fig 1. The APSIM model component uses climatic and soil data to simulate plant growth. Three APSIM 'paddocks' (milpa, Guinea grass, and corral) are simulated simultaneously. The Vensim™ model component details management, flock dynamics, sheep production, partitioning of nutrients, labor, and economic outcomes. Data outputs from numerous SRNS (Small Ruminant Nutrition System) simulations are contained within the Vensim™ model. The Venlink module in APSIM enables APSIM and Vensim™ to communicate daily with specific variables. This structure allows communication between all parts of the model, enabling the reproduction of numerous system feedbacks.
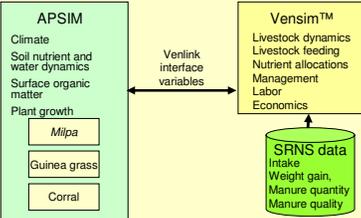

Fig 1. Outline of the Integrated Model.

Scenario analyses
What are the biophysical and household outcomes from differing:
1. Types of farms (sheep vs. crop vs. sheep & crop).
2. Manure management and use practices
3. Livestock feeding practices
Only the results for the third scenario group are presented in this poster. The aim is to represent combinations of practices, but not to simulate and predict the circumstances that lead to farmers choosing these practices.
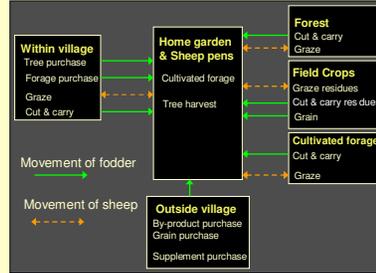

Fig 2. Nutrient flows in livestock feeding practices in Yucatán.

Livestock Feeding Practices
A key hypothesis is that the practices used to feed animals is a key determinant of nutrient flows and hence the outcome of the system (see Fig. 3). What feeding pathways are used, and whether fodders and nutrients are physically moved or moved by sheep makes a difference.

Feeding Option Descriptions
A – Graze common land
B – Cut and carry (C&C) common land
C – Graze common land + stover for mature ewes
D – C&C common land + stover for mature ewes
E – C&C common land + grain for growing sheep
F – C&C grass + C&C 'Leucaena'
G – C&C grass + commercial supplement
H – Graze grass
I – Graze grass + commercial supplement
Note – The model aims to maintain 11 ewes and 2 rams. All lambs and growing ewes are fed some grain.

Results
Results for livestock expenses, livestock labor, returns to labor, and labor and management income, are shown in Figures 3-6.
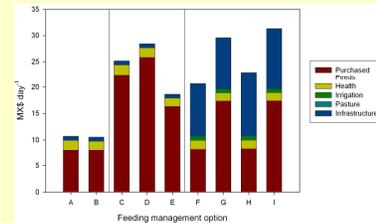

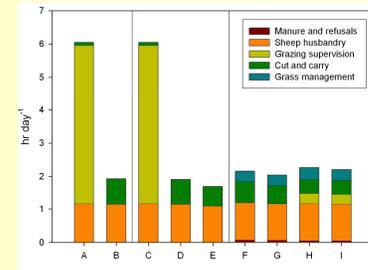Fig 3. Components of livestock enterprise expenses.
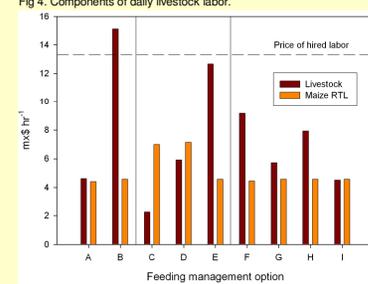

Fig 4. Components of daily livestock labor.
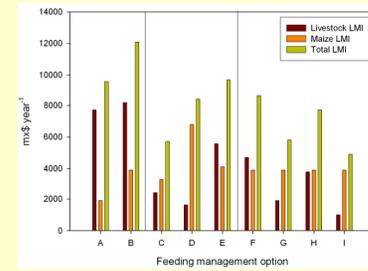

Fig 5. Livestock and *milpa* returns to labor (RTL).

Fig 6. Livestock, *milpa*, and combined labor and management income (LMI).

Discussion

Implications of model outputs
• It is logical for smallholders make use of the natural resources available e.g. focus on using common land and native tree legumes such as *Leucaena leucocephala*.
• Supplementing to improve live-weight gains can often decrease net income.
• Cut and carry systems can be more labor efficient than grazing systems (if continuous supervision is needed).
• Investment in increased integration through the use of crop by-products may not be a favorable option when common land is available.
• Investment in infrastructure to grow improved forages may lead to decreased returns to labor and net income.

Model limitations and improvements
• Phosphorus is an important nutrient but the grass module in APSIM does not track P, and neither does SRNS.
• A wider range of crop & forage modules are needed in APSIM.
• Volatilization is not included in APSIM.
• Only one soil type, and one milpa was simulated.
• Potential to define spatial relationship between locations.
• Lack of knowledge of the underlying processes of manure decomposition, particularly manure surface applied and in piles.
• Feed quality data that is not generated by APSIM (e.g. neutral detergent fiber, lignin) is needed to generate SRNS runs.
• A dynamic SRNS would offer numerous benefits.

References
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• Thornton, P.K., and M. Herrero. 2001. Integrated crop–livestock simulation models for scenario analysis and impact assessment. Agricultural Systems 70: 581–602