Future of Crop-Livestock Systems in the densely populated highlands of Kenya

Van de Steeg\textsuperscript{a}\textsuperscript{§}, Jeannette, Peter Verburg\textsuperscript{b}, Isabelle Baltenweck\textsuperscript{a}, Mario Herrero\textsuperscript{a}, Stella Makokha\textsuperscript{c} and Steve Staal\textsuperscript{a}

\textsuperscript{a} International Livestock Research Institute (ILRI), P.O. Box 30709, 00100 Nairobi, Kenya
\textsuperscript{b} Wageningen University, The Netherlands
\textsuperscript{c} Kenya Agricultural Research Institute (KARI), Kenya
\textsuperscript{§} Contact person, email: j.vandesteeg@cgiar.org

Abstract

As a result of demographic change in the densely populated highlands of Kenya, farming systems are changing. In this area a large majority of smallholders integrate crops (for food and cash) and dairy production to diversify risks from dependency on a single crop or livestock enterprise. Mixed farming yields complementarities in resource use: crop residues and by-products from crop production constitute feeds for cattle, which return manure to maintain soil fertility and crop production. Land use and/or farming systems are mostly studied at the household level, the unit of decision making. Linking spatial patterns of biophysical and socio-economic conditions to farming systems characteristics can be used in order to identify the spatial distribution of farming systems. The resulting spatial distribution of farming systems can be used for land use research analysis. Logit regression function analysis was used to reveal and quantify the relations between farming systems and a set of explanatory factors. Based on the biophysical (like climate and soil properties) and socio-economic conditions (like market access and population density) of a location the relative probability of finding the different farming systems at that location was defined. Scenarios developed with a wide range of stakeholders, each representing a possible development path for Kenya, were used to study the effect of temporal dynamics of the set of explanatory factors on the spatial distribution of farming systems. Changes in population density and related factors like infrastructure and market accessibility were found to be important factors explaining this spatial distribution. A household model was used to study the consequences of the systems evolution at the household level. Projected changes in these farming systems are expected to have large impact on vegetation cover, nutrient cycling and landscape characteristics.

1 Aim and objectives of the study

To improve opportunities for smallholder producers to participate in the increasing global demand for livestock products, by developing and applying new tools and understanding to target policies, planning and technologies.

Specific objectives of this project are:

- Identify patterns of systems evolution and trajectories of change in crop-ruminant systems, and elucidate the main driving forces of change.
- Model the common (transregional) relationships between driving factors and change in targeted sites, and predict system evolution.
2 Methods

2.1 Categorizing and mapping crop-livestock production systems
The first step was to identify homogenous farming systems, based on household level data. A total of five farming systems were identified, based on type of crops grown (distinction between farmers growing cash crops for export and other farmers), use of fertilizer and dairy intensification. An additional class of non agricultural households was also considered.

2.2 Modeling general trajectories of change with CLUE modeling framework
Logit regression analysis was then used to link the farming system to a set of explanatory variables, either survey- or GIS-derived. Explanatory variables included farm and farmer’s characteristics, agro-physical conditions, human population density and market access indicators. The 2004 base map of farming system was then generated by predicting farming system distribution using the values of the explanatory variables for which GIS layers were available. The last step was to predict temporally and spatially farming system evolution with CLUE modeling framework\(^1\) under the different scenarios by translating the storylines into different values of the explanatory variables. Temporal explanatory variables considered in the analysis are: human population density, access to education, use of extension services, off-farm income, market accessibility, and climate.

2.3 Using household model (IMPACT) to validate the impact of systems changes
A household model\(^2\) (using linear programming method) is used to validate the impact of these changes at a micro level. The household model predicts relatively similar change to the spatial model. The effects of the different scenarios on the household were finalized, and compared to the outcomes predicted from the CLUE modeling.

2.4 Scenarios
A key element of this project was to simulate crop-livestock system change under contrasting hypothetical scenarios of policy direction and investment choices. In that way, the effects of different policies can be assessed on different locations in the target area. Kenya’s Economic Recovery Strategy for Wealth and Employment Creation\(^3\) has laid out the country’s vision of a “working nation”. The focus is on giving economic empowerment and democracy to Kenyans, through the restoration of economic growth, generation of employment, and reduction of poverty levels. For this project possible development paths for agriculture in the Kenyan Highlands over the next 20 years are described in so-called storylines. These storylines are based on the implementation of the Economic Recovery Strategy (ERS) for Wealth and Employment Creation in one case, and on several alternative policy and development scenarios in the other cases, and predicts the implications of these alternative development choices on the agricultural sector.

3 Description of the research area
The study area (approximately 65,000 km\(^2\)) covers the highlands of Kenya. Crop production in the Kenyan Highlands is often integrated with dairy production to diversify risks from dependency on a single crop or livestock enterprise. Mixed farming yields complementarities in

resource use: crop residues and by-products from crop production constitute feeds for cattle, which return manure to maintain soil fertility and crop production.

4 Results

Table 1 presents the number of observations by farming systems, based on an experts-based classification.

<table>
<thead>
<tr>
<th>Cluster</th>
<th>Farming systems</th>
<th>Nr of observations</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Subsistence farmers with limited dairy activities</td>
<td>465</td>
<td>14.1</td>
</tr>
<tr>
<td>2</td>
<td>Farmers with major dairy activities</td>
<td>555</td>
<td>16.9</td>
</tr>
<tr>
<td>3</td>
<td>Intensified crop farmers with limited dairy activities</td>
<td>753</td>
<td>23.0</td>
</tr>
<tr>
<td>4</td>
<td>Export cash crop farmers with limited dairy activities</td>
<td>622</td>
<td>19.0</td>
</tr>
<tr>
<td>5</td>
<td>Export cash crop farmers with major dairy activities</td>
<td>457</td>
<td>13.9</td>
</tr>
<tr>
<td>6</td>
<td>Non agricultural households</td>
<td>428</td>
<td>13.1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>3,280</strong></td>
<td><strong>100</strong></td>
<td></td>
</tr>
</tbody>
</table>

The goodness of fit indicators of logit regression analysis is indicated in Table 2. Explanatory variables included are: gender, age and level of education of household head, number of adults in the household, proportion of adults with off-farm activities, proportion of households in the sub-location who use extension services, the farm size (ha), average land rented in the sub-location (ha), pH, CEC, relief, elevation (m), human population density, travel time to the nearest large urban centre (h), and length of growing period (days).

The base map showing the distribution of the farming systems is given in Figure 1, as well the changes in farming systems that are likely to occur in 2024 (compared to 2004) under the different scenarios. Table 3 presents a summary of the simulated changes in farming systems between 2004 and 2024, in terms of percentage of land cover. On average 20% of the surface area in the study area is expected to change under the different scenarios. Of this change, more than a quarter will turn into more intensified farming systems (including those with intensive crop cultivation and export oriented systems). Moreover, a large percentage of the farming systems will shift towards export-oriented farming systems.

<table>
<thead>
<tr>
<th>Change (in percentage)</th>
<th>Baseline</th>
<th>Equitable</th>
<th>In-equitable</th>
</tr>
</thead>
<tbody>
<tr>
<td>No change</td>
<td>80.6</td>
<td>74.8</td>
<td>97.0</td>
</tr>
<tr>
<td>Less intensified farming systems</td>
<td>8.9</td>
<td>4.7</td>
<td>22.4</td>
</tr>
<tr>
<td>More intensified farming systems</td>
<td>27.0</td>
<td>34.1</td>
<td>4.2</td>
</tr>
<tr>
<td>Change towards export-oriented farming systems</td>
<td>53.2</td>
<td>66.2</td>
<td>40.7</td>
</tr>
<tr>
<td>Change towards non export-oriented farming systems</td>
<td>8.0</td>
<td>1.7</td>
<td>23.8</td>
</tr>
</tbody>
</table>

* Zone without large-scale farming
** Zone without large-scale farming
A household model (using linear programming method) is used to validate the impact of these changes at a micro level. The household model predicts relatively similar change to the spatial model. For the equitable growth scenario for example, in the case of subsistence and intensified farmers with dairy, it is observed at the household level that the farmer will start growing passion fruit while keeping the dairy herd relatively constant. This result is consistent with the prediction of the spatial model. On the other hand, the shift towards dairy seen for export cash crops farmers in the spatial model is not observed in the household model (number of cows remains constant throughout the period). For the specific farmer representative of this group, the land consolidation seen under this scenario is not sufficient to compensate for the large increase in labour costs experienced under this scenario.

5 Conclusion and Recommendations

Changes in population density and related factors like infrastructure and market accessibility are found to be important factors explaining the spatial distribution of farming systems and are the main drivers of farming system change in the Kenyan Highlands. Land fragmentation, due to population growth, has major impact on system change at household level. Projected changes in these farming systems are expected to have large impact on the supply with agricultural commodities and food, as well on agricultural ecosystems.

These results are only indicative of potential changes under rather simplistic scenarios, and so should not be seen as definitive. Their main purpose is to stimulate interest of policymakers and decision makers, and to enhance the discussion about the effect of certain policy measures and the future of agriculture in Kenya in general.