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Using Multi-Objective Optimisation for Mixed Smallholdings in Amhara Region, Ethiopia, for Food Systems Transition

[Improving food systems in less-favoured areas in East Africa/ KB-35-003-001]

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Objective: To identify and evaluate potential farm configurations that maximize farm economics, contribute to regional food and nutrition security, and minimize the environmental footprint.

Methodology: Farm optimization using the **FarmDESIGN** model.
Our multi-objective optimization procedure maximizes (i) farm operating profit, (ii) tropical livestock units, (iii) dietary energy yield, and (iv) vitamin A yield; and minimizes (v) GHG emissions and (vi) nitrogen soil losses.

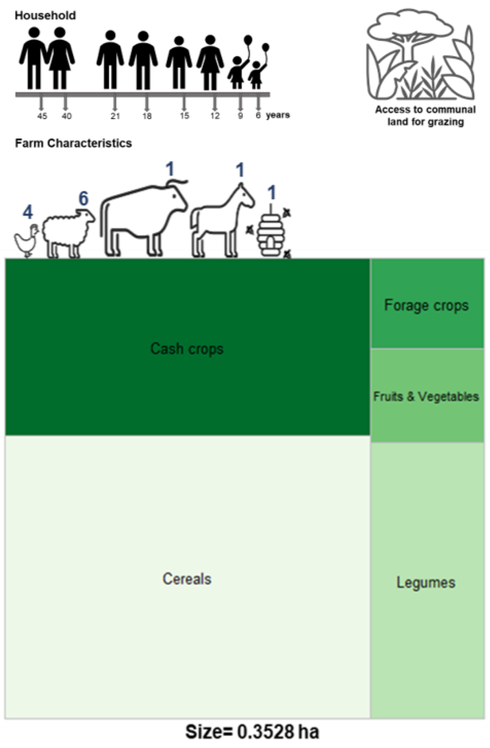

Figure 1. Original farm configuration for a medium-sized farm in Lay Gayint (MLG)

Farm types:
We looked at two farm types (medium and small scale) in two different districts of the Amhara region (South Achefer = high potential area, Lay Gayint = low potential area), in Ethiopia (**Fig. 1**). Moreover, the four farms differed in terms of cultivated crops, livestock types and numbers, which led to different farm performance levels.

Results: Pairwise analysis of the multi-objective optimization presents clear differences in size, form and positioning of the solution spaces for each farm (**Fig. 2**).

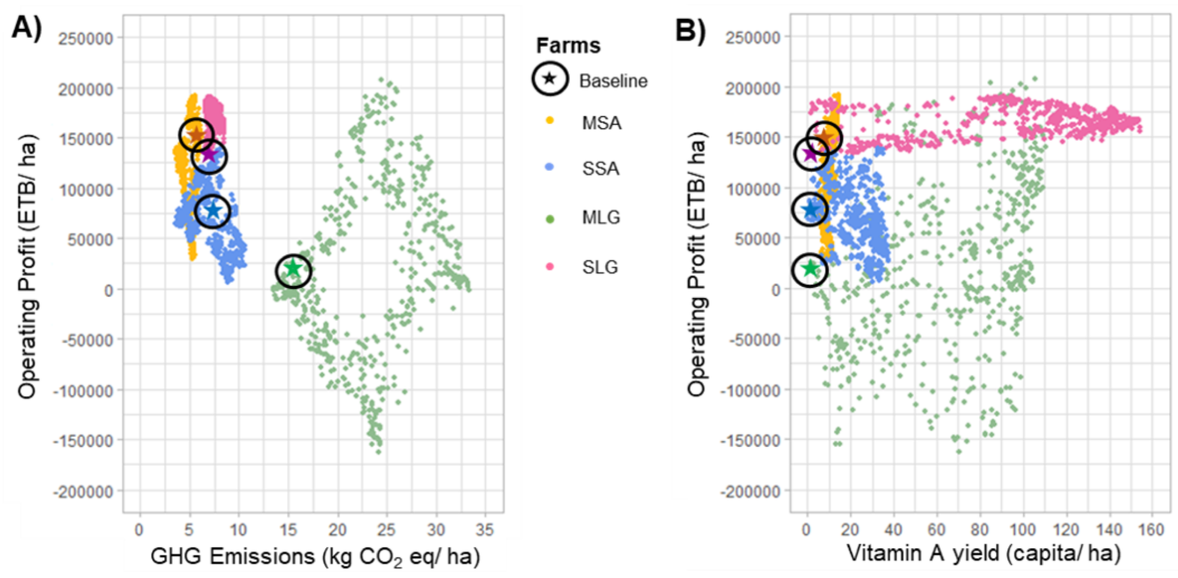

Figure 2. Opportunity space for different farms as delimited by the pairwise comparison of objectives. Here exemplarily shown for one economic, environmental and nutritional objective.

Conclusions:
The proposed reconfiguration of the farm types according to the six objectives and farm type-specific constraints, shows that, in general, (1) the production of vitamin A (Fig. 2 B), and the fraction of manure added to the soil could be increased without negative effect on operating profit, and (2) the area of cereals and other crops must and can be reduced to make room for crop diversification.
Fig. 3, as an example, shows details of the reconfiguration based on the ten most optimal solutions for MLG farms:

- Increase in livestock units - chickens and one crossbred cow
- Increase area of cash crops (eucalyptus and garlic)
- Decrease fava bean and cereal area in favour of potatoes (energy yield)
- Incorporation of species for vitamin A, such as beetroot, Ethiopian kale, carrots, and pumpkins.

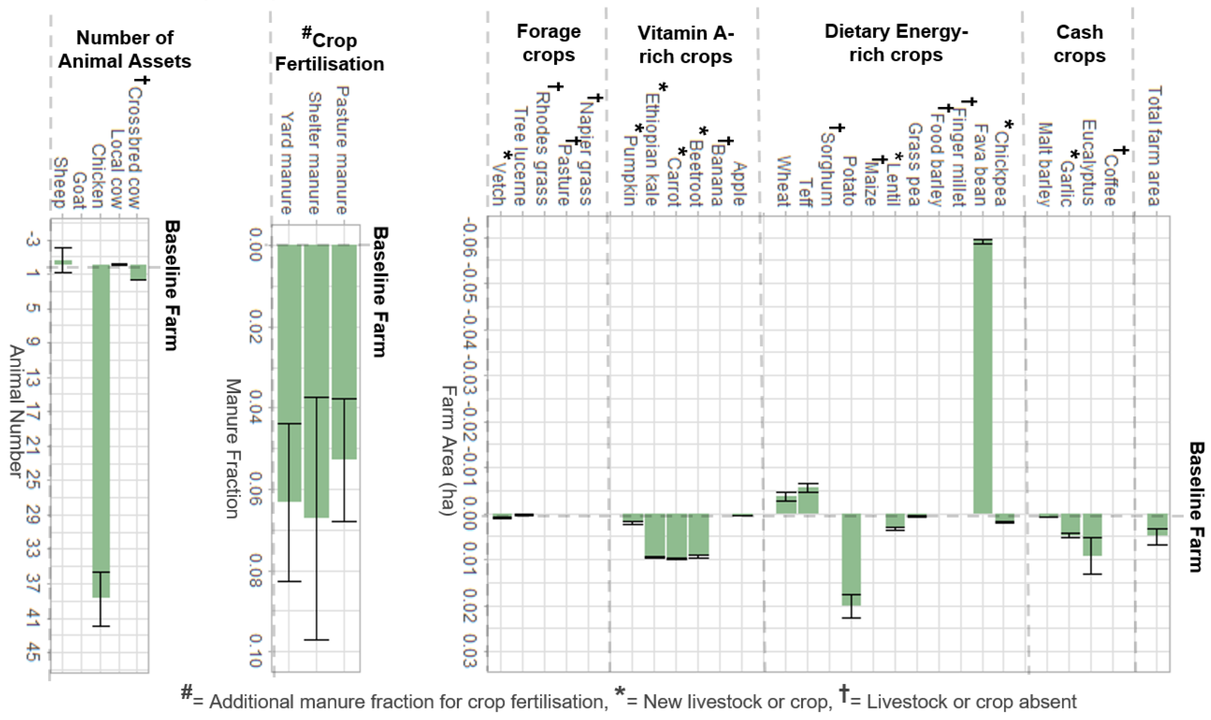

Figure 3. New farm configurations according to the average of the ten top-scoring solutions for MLG farms

Contribution to transition: Using multi-objective optimization, we explored 'solution spaces' for different farm types, comprising of crop and livestock combinations and management configurations that satisfy household objectives, regional food & nutrition security and environmental objectives. Farm types varied in objective response because of the heterogeneity in natural resource availability and access to markets. Reconfiguring cropping patterns and livestock composition offered all four farm types options to increase profit and vitamin A yield, adjust energy yield, and decrease nitrogen losses and GHG emissions.

External partners

Ethiopian farmers organizations, input suppliers, government agencies, NGOs for farm type characterisation, data collection and first validation of results.

What's next?

Discuss proposed farm reconfigurations with farmers & other decision makers to better understand the opportunities and constraints for system transformation and adoption of suggested changes (farm to food system level).
Explore applicability of multi-objective optimization as multi-disciplinary method in agricultural planning and extension.

Questions for the audience

- What other scenarios do you think are interesting to analyse?
- What are implications of this study for other components of the food system?
- What is a link to your work? What can you offer that is useful for us?

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https://www.wur.nl/en/Research-Results/Research-funded-by-the-Ministry-of-LNV/Expertisegebieden/kennisonline/Improving-food-systems-in-less-favoured-areas-in-East-Africa-1.htm

Key publications

Deolu-Ajayi, A.O.; Alvarez Aranguiz, A.B.; Ndambi, O.A.; Vernooij, A.G.; Wosten, J.H.M.; Siegmund-Schultze, M.G.R.; Lee, J. van der. Farming System Models (2020).
Soethoudt, J.M. , Oostewechel, Rene , Deolu-Ajayi, Ayodeji , Janssen, Valerie , Ndambi, O.A. , Siegmund-Schultze, Marianna , Hengsdijk, H. Back to office report Ethiopia Field trip December 2019.
Ayodeji Deolu-Ajayi, Asaah Ndambi, Marianna Siegmund-Schultze, Adolfo Alvarez Aranguiz, Yihenew G. Selassie, Yenesew Abebe, Jeroen Groot, Hanneke Heesmans, Carlos Alho, Jan van der Lee, Huib Hengsdijk. Identifying pathways to increase food security in the Amhara region of Ethiopia – combining farm modeling with the food systems approach (in progress).