ASSESSMENT TOOL / MODEL **FarmDESIGN: Analysis and (re)design of farming systems**

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FarmDESIGN is a decision support tool intended for use by agronomists that utilizes farm data to evaluate a farm's current performance for multiple objectives, and then generate sets of alternative farm configurations based on set biophysical and socio-economic objectives. Trade-offs and synergies between objectives can be modeled based on the sets of alternative farm configurations set by the user.

NOTE Examples of this tool in use are included as a case study at the end of this learning material.

Overview

FarmDESIGN is a bio-economic whole-farm model developed for analysis and design of farm systems. This is a static model that quantifies the productive, economic and environmental performance of a farm system where multiple components come together: soil, crops, livestock, household member behavior and decision making. Pareto-based optimization allows configuration of 'windows of opportunities' for the farm system and allows identification of trade-offs and synergies between performance indicators.

Relevance of the level of analysis

The household is the most common economic and decision making unit. This is the level that individual farmers can act on and change, where farm management reflects directly on the production system. Around the world, the household forms a strong unit of agricultural production for both crops and livestock, with tight interdependencies between decision making and exchanging and sharing resources - tools, labour, capital and food - from the various crop and livestock components of the farm.

Model/tool description

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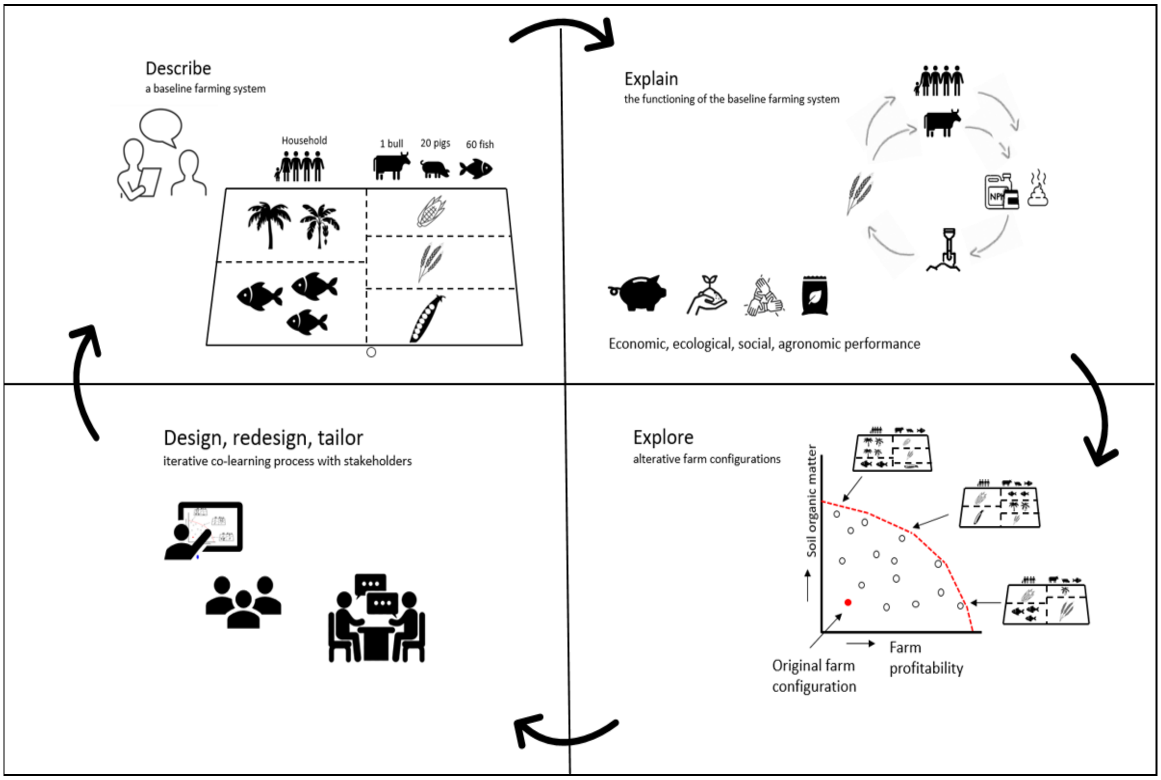


Figure 1. *FarmDESIGN supports iterative cycles of learning & adaptation*

The whole-farm model follows the 4-step DEED-cycle -- Describe, Explain, Explore and Design.

1. As a starting point, the farm household system is described through parameters covering household composition (e.g. how many people live there, what are the household members on- and off-farm activities, etc.), the farm environment (e.g. climate and soils), context-specific economics (e.g. farm expenses and labour prices), crops and animals with their related products (e.g. yields, labour required and destinations), other farm inputs (e.g. manures and fertilizers), and farm infrastructure (e.g. buildings and machinery).
2. In the second step, the system is explained through economic, social, environmental and nutritional indicators.
3. In the third exploration step, the different parameters used to describe the system can be set as decision variables (i.e. with upper and lower limits on, for instance, crop areas), and some of the indicators used to explain the system can be set as constraints (i.e. upper and lower limits on animal's energy and protein requirements) or as outcome objectives to maximise or minimise. The model runs a Pareto-based Differential Evolution algorithm to generate numerous possible configurations and display them within a solution space8. The trade-offs, and more importantly the synergies, that emerge out of the solution spaces can illuminate the potential forward trajectories for farmers.
4. In the fourth and final step, a suitable solution can be chosen as a (re)design option for the farm.

In these 2 videos, Dr. Jeroen Groot introduces FarmDESIGN and discusses trade-offs, synergies and connection to other scales.

Introduction to FarmDESIGN - https://vimeo.com/637390531

Trade-offs and synergies - https://vimeo.com/637390895

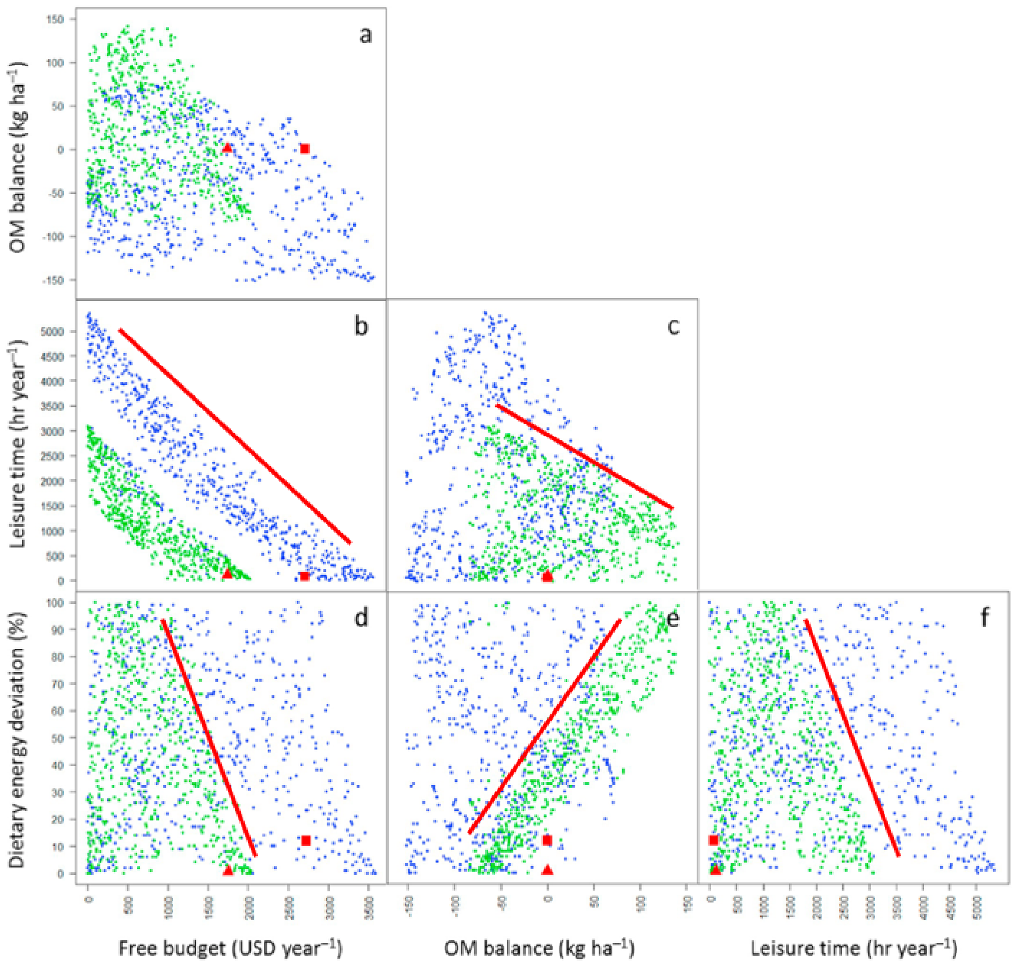


Figure 2. *Using FarmDESIGN graphic outputs to visualize tradeoffs and synergies between the defined objectives for two farms in Vietnam Each dot indicates an alternative farm configuration. The red symbols mark the performance of the original farm configuration.*

What is the development stage of the tool? What are its strengths and weaknesses? What are the gaps and next steps?

FarmDESIGN offers a structured way to quantify how farms perform. It gives insights into the functioning and its consequences, to the environment, to labor demands, nutrition. In addition, it generates options for redesign which can be inspirational for discussion with advisors, farmers and researchers. The model demands background data, which is quite labor demanding. The model is static, it provides a snapshot of farm performance, so it does not give an overview of processes in time. The model has been developed over the past 25 years. With the new digital age, with new possibilities for available data and spatial data we explore new avenues to implement that in for example in web based environments. It is in the interest of partners and the developers to further implement these things and improve the model.

In this video, Dr. Jeroen Groot discusses these issues in more depth - https://vimeo.com/637390869

Details for potential users

Proposed users - agronomists, researchers, students
Model input - ● household survey(s) responses: ● household composition (people) ● farm expenses - costs/income, labour prices, etc. ● crops & livestock - products, yields, labour needs, use (on/off farm), water demands ● other inputs (pesticides, fertilizers, etc.) ● farm infrastructure - buildings, machinery, value of these elements ● subsidies / other economic support ● secondary data: ● nutritional composition of food/feed ● climatic data ● soil data ● commodity prices

Model output -

- Flows of nitrogen, phosphorus and potassium to, through and from a farm, computes the feed balance based on energy and protein, nutrition, the amount and composition of manure, labour distribution and farm economics.
- The 'window of opportunities' of a farm: a set of potential farm configurations that differ in performance on objectives.
- Relationships between set objectives: trade-offs and synergies

Key terms

- **Farm system** - a decision making unit comprising the farm household, cropping and livestock systems, that transform land, capital (external inputs) and labour (including genetic resources and knowledge) into useful products that can be consumed or sold (2)

- **Farming system** - a population of individual farm systems that may have widely differing resource bases, enterprise patterns, household livelihoods and constraints (3)

- **Whole-farm model** - Model taking into account all components of the farm system. This view is indispensable to analyse the integrated character of the farm (4)

- **Decision support tool -** Tool with the potential to support learning and decision-making processes of farmers and advisers (5)

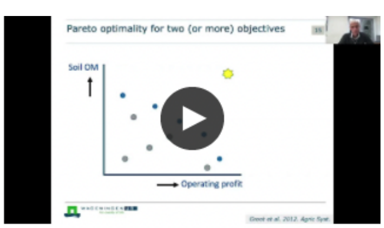
- **Solution space/window of opportunities** - Set of potential farm configurations that differ in performance on objectives. In literature also referred to as solution space, outcome space or opportunity space (4)

- **Pareto optimalit**y - The entity (farm, household, system) outperforms other households with equivalent characteristics in at least one dimension without being outperformed in any other dimension (6)

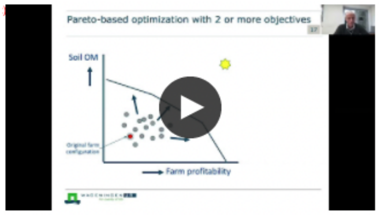
- **DEED-cycle -** Phases of Describe, Explain, Explore and Design, to guide process of co-learning amongst researchers, farmers and other stakeholders (7)

Manuals, tutorials, or other learning materials:

- FarmDESIGN uses Pareto based optimization. The original farm configuration is the starting point for the optimization, which results in alternative farm configurations. An evolutionary algorithm searches for improvements of this farm configuration relative to the current situation, based on the objectives, constraints and decision variables as seen in these 2 videos.



https://vimeo.com/637395278 (pareto-video 1)



https://vimeo.com/637395321 (pareto-video 2)

Key references

Ditzler, L., Komarek, A.M., Chiang, T.-W., Alvarez, S., Chatterjee, S.A., Timler, C., Raneri, J.E., Carmona, N.E., Kennedy, G., Groot, J.C.J., 2019. A model to examine farm household trade-offs and synergies with an application to smallholders in Vietnam. Agric. Syst. 173, 49–63. https://doi.org/10.1016/j.agsy.2019.02.008

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2 - Fresco, L.O.; Westphal, E., 1988. A hierarchical classification of farm systems. Exp. Agric. 24.

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Case Study - Smallholder farm and farmer diversity in Ghana

Time period (or an indication): 3 years
Key actors/stakeholders/beneficiaries: reseachters, policy/decision makers, indirectly smallholder farmers

Applying the model: Effective land management and allocation is leading in how well smallholder farmers in Ghana will be able to sustain their livelihoods. The FarmDESIGN model was used to explore a farms "room to manoeuvre" and offered insights into how the land could be used and be best for sustainable and more intensive production. Many technical possibilities were found, but what did they mean to the farmers? The same technical solution appeared to be received differently by different household members, due to their different roles. Men were responsible for growing staple crops, while women were responsible for nutritional diversity, young men preferred cash crops. Their different position and power interrelations in the household defined decision making on land allocation.

In this video, Dr. Mirja Michalscheck with Africa RISING discusses this case study in more depth
https://www.youtube.com/watch?v=6ZS31sv7Hs0

Literature for further reading and details:

- Michalscheck, M. et al. (2018) Model results versus farmer realities. Operationalizing diversity within and among smallholder farm systems for a nuanced impact assessment of technology packages
https://www.sciencedirect.com/science/article/pii/S0308521X17306303

- Michalscheck, M. et al. (2020). Land use decisions: By whom and to whose benefit? A serious game to uncover dynamics in farm land allocation at household level in Northern Ghana.
https://www.sciencedirect.com/science/article/abs/pii/S0264837719307951

Questions for reflection:

1. Why is the farm level relevant to study?
2. Can you come up with trade-offs specific to the farm context?
3. Can you think of advantages and drawbacks of generating a large set of alternatives in comparison with formulating just one optimal alternative?

Explore other case studies...

The use of FarmDESIGN in Bihar, India

Time period (or an indication): 2016-2019
Key actors/stakeholders/beneficiaries: local research-community
A presentation of the results of the case-study ***Using a positive deviance approach to inform farming systems redesign: A case study from Bihar, India:*** ***Link***

Literature for further reading and details:

- Adelhart Toorop, R., Ceccarelli, V., Bijarniya, D., Jat, M.L., Jat, R.K., Lopez-Ridaura, S., Groot, J.C.J., 2020. Using a positive deviance approach to inform farming systems redesign: A case study from Bihar, India. Agric. Syst. 185, 102942. https://doi.org/10.1016/j.agsy.2020.102942

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Redesign of a mixed farm in The Netherlands, student assignment, 3 weeks of work

Time period (or an indication): 2019
Key actors/stakeholders/beneficiaries: farmers
Applying the model: Explore the case study further here
https://drive.google.com/file/d/1LXaBetIt5mksInL3pNNegV8qWL1cE1kt/view?usp=sharing