



ASSESSMENT TOOL / MODEL **decisionSupport: Quantitative Support of Decision Making Under Uncertainty**

Cory Whitney, Associate Scientist / University of Bonn, Germany

Eike Luedeling, Head of Horticultural Sciences Department / University of Bonn, Germany

Decisions in agriculture are often risky, meaning that decision makers have uncertainty about how their decision will influence the intended outcomes. Decision Analysis provides a set of approaches that are aimed at capturing what is known and applying this knowledge to generate forecasts of decision outcomes. The foundations and inputs of the decisionSupport tool are based on transdisciplinary approaches that take a holistic view of long-term sustainability.

NOTE An example of this tool in use is included as a case study at the end of this learning material.

Overview

Technically, the decisionSupport tool is a collection of functions in the R programming language, designed to support the quantitative analysis of binary welfare-based decision-making processes using Monte Carlo simulations. Decision support is given on two levels:



1. The actual decision level is to choose between alternatives under probabilistic uncertainty. The tool calculates the optimal decision based on maximizing expected welfare.
2. The meta decision level is to allocate resources to reduce the uncertainty in the underlying decision problem, i.e. to increase the current information to improve the actual decision-making process. This problem is dealt with using the Value of Information Analysis. The Expected Value of Information for arbitrary prospective estimates can be calculated as well as Individual Expected Value of Perfect Information. The probabilistic calculations are done via Monte Carlo simulations.

Figure 1. Logo for the decisionSupport tool in the R programming language

https://cran.r-project.org/web/packages/decisionSupport/vignettes/example_decision_function.htm

Relevance of the level of analysis

Decisions in agriculture are often risky, meaning that decision makers have uncertainty about how their decision will influence the intended outcomes. Farming systems are dynamic and the impact of any intervention, policy or management decision is likely to be influenced by many factors ranging from soil and crop dynamics to social dynamics such as farmer and community perceptions. In order to provide scientific support for decision making it is important that our models and forecasts attempt to include these interactions. Decision Analysis provides a set of approaches that are aimed at capturing what is known and applying this knowledge to generate forecasts of decision outcomes.

Model/tool description

Many of the variables decision makers need to consider in development cannot be precisely quantified, at least not without unreasonable effort. The major objective of (prescriptive) decision analysis is to support the decision-making processes when faced with this problem (Luedeling and Shepherd 2016). Decision analysis can make forecasts of decision outcomes without precise numbers.

The decisionSupport package (Luedeling et al. 2021) implements this as a Monte Carlo simulation, which generates a large number of plausible system outcomes, based on random numbers for each input variable, drawn from user-specified probability distributions. The model simulation tool requires two inputs:

1. an R function that predicts decision outcomes based on the variables named in a separate data table. This R function is customized by the user to address a particular decision problem to provide the decision analysis model.
2. an input table (in .csv format) specifying the names and probability distributions for all variables used in the decision model. These distributions aim to represent the full range of possible values for each component of the model.

These two inputs are provided as arguments to the mcSimulation function, which conducts a Monte Carlo analysis with repeated model runs based on probability distributions for all uncertain variables. The data table and model are customized to fit the particulars of a specific decision.

Details for potential users

Proposed users - farmers and agricultural decision makers such as those in government ministries and aid organizations

Key actors/stakeholders/beneficiaries - farmers and agricultural decision makers such as those in government ministries and aid organizations who are faced with uncertain decisions and the stakeholders to be affected by those decisions

Model input

1. Programmed version of the holistic assessment of the proposed decision impact pathway / theory of change linking the decision to be made (alternatives to be assessed) and their intended and expected impacts on the outcome or outcomes of interest
2. Table of quantitative variables with information about the expected distributions of each

Model output - Comparative distributions of the expected impact of the decision options on the outcome(s) of interest

Time period for different steps of model use and analysis - The process generally takes 1-2 months but can take longer depending on the complexity of the decision problem and the level of active participation of stakeholders and decision makers

Key terms

- **Decision** - A situation that requires a decision maker to choose between alternatives (mutually exclusive resource allocations) with outcomes that have differing desirability and likelihoods
- **Decision analysis** - discipline / philosophy / methodology / professional practice to formally address, assess and support decision making under uncertainty
- **Risk** - a chance or situation involving the exposure to a possibility of loss, injury, or other adverse or unwelcome outcome
- **Uncertainty** - a lack of certainty and inability to exactly describe a current or future state of a factor of interest
- **Measurement** - Any action that serves to aid in the reduction of uncertainty

Manuals, tutorials, or other learning materials:

- Applying the mcSimulation function in decisionSupport
https://cran.r-project.org/web/packages/decisionSupport/vignettes/example_decision_function.html
- Controlled burns in conifer forests
https://cran.r-project.org/web/packages/decisionSupport/vignettes/wildfire_example.html

Key references

Luedeling, Eike, and Keith Shepherd. "Decision-Focused Agricultural Research." *Solutions* 7, no. 5 (2016): 46–54.

Luedeling, Eike, Lutz Goehring, Katja Schifffers, Cory Whitney, and Eduardo Fernandez. *DecisionSupport – Quantitative Support of Decision Making under Uncertainty*. Contributed Package to the R Programming Language. Version 1.106. R programming language, 2021.
<https://cran.r-project.org/web/packages/decisionSupport/index.html>.

Do, Hoa, Eike Luedeling, and Cory Whitney. "Decision Analysis of Agroforestry Options Reveals Adoption Risks for Resource-Poor Farmers." *Agronomy for Sustainable Development* 40, no. 3 (June 2020): 20. <https://doi.org/10.1007/s13593-020-00624-5>.

Lanzanova, Denis, Cory Whitney, Keith Shepherd, and Eike Luedeling. "Improving Development Efficiency through Decision Analysis: Reservoir Protection in Burkina Faso." *Environmental Modelling & Software* 115 (May 1, 2019): 164–75. <https://doi.org/10.1016/j.envsoft.2019.01.016>.

Whitney, Cory, Denis Lanzanova, Caroline Muchiri, Keith D. Shepherd, Todd S. Rosenstock, Michael Krawinkel, John R. S. Tabuti, and Eike Luedeling. "Probabilistic Decision Tools for Determining Impacts of Agricultural Development Policy on Household Nutrition." *Earth's Future* 6, no. 3 (2018): 359–72. <https://doi.org/10.1002/2017EF000765>

Case Study - Outline of mathematical model development used to calculate Net Present Values (NPV) of agroforestry interventions promoted in Northwest Vietnam

Time period (or an indication): It took us about 6 months to implement this particular decision model

Key actors/stakeholders/beneficiaries: The specific model results are meant to serve decision making regarding agroforestry interventions in the Northwestern uplands of Vietnam. The results and methods provide a framework for the design of future policies for sustainable development and for further analyses of agroforestry interventions.

Applying the model: We derived expert knowledge from groups of farmers, groups of experts, and mixed groups consisting of both farmers and experts in Northwest Vietnam. We used the information from them and other sources to develop a mathematical model that we then used to calculate Net Present Values (NPV) of the different agroforestry interventions that decision makers are considering promoting in the region. This process was implemented in the R programming language. To illustrate the modeling procedures we highlight NPV calculations for the decision to choose coffee-based agroforestry systems (combinations of coffee, teak, plum, annual crops and grass) over conventional monocultures of maize. The same procedures and functions can be used for the other interventions.

The corresponding input data tables for each system are provided in the rest of the supplementary materials.

http://htmlpreview.github.io/?https://github.com/dohoa1190/Supplementary-materials/blob/master/Methodology_outline.html

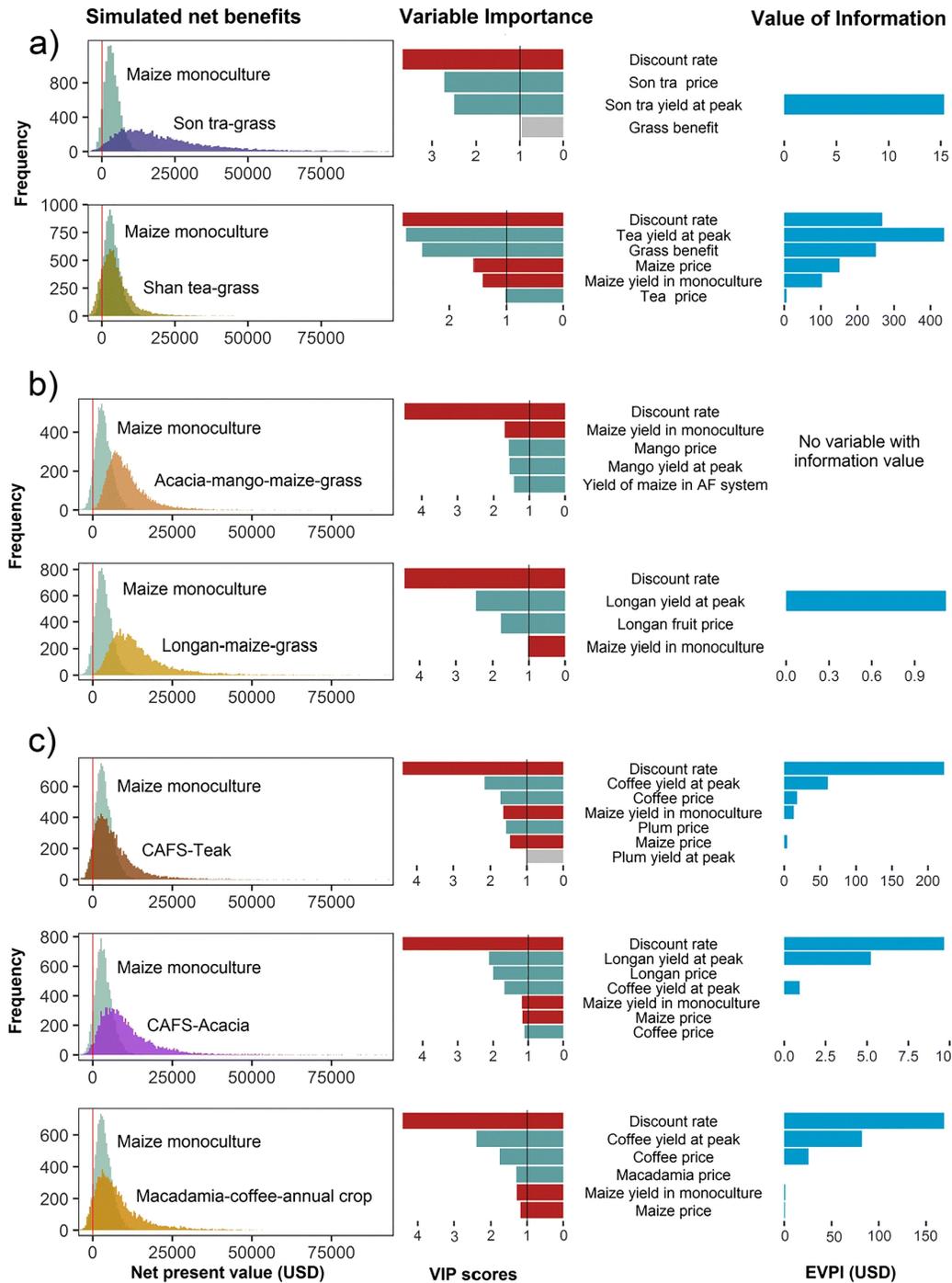


Figure 2. Probabilistic analysis of agroforestry intervention decisions in Northwestern Vietnam: **a** implement simple agroforestry systems vs. maize monoculture, **b** implement maize-based agroforestry systems vs. maize monoculture, and **c** implement coffee-based agroforestry systems vs. maize monoculture. Histograms (left) present the Net Present Values of 10,000 Monte Carlo simulation runs of agroforestry and maize monocultures. Bar graphs (right) indicate variable importance (expressed by VIP scores) for variables to which the model was most sensitive (green bars indicate positive relationships with the outcome variables, red bars indicate negative relationships, gray bars indicate variables with VIP scores less than 1) and value of information calculated as Expected Value of Perfect Information (EVPI) in USD.

Literature for further reading and details:

- Do, Hoa, Eike Luedeling, and Cory Whitney. “Decision Analysis of Agroforestry Interventions in Northwest Vietnam.” Zenodo, March 26, 2020. <https://doi.org/10.5281/ZENODO.3727576>.
- “Decision Analysis of Agroforestry Options Reveals Adoption Risks for Resource-Poor Farmers.” *Agronomy for Sustainable Development* 40, no. 3 (June 2020): 20. <https://doi.org/10.1007/s13593-020-00624-5>.
- For an interactive website related to this tool for those interested in exploring further details please visit: https://cory-whitney.shinyapps.io/Decision_Analysis_Course/#section-decision_analysis