Agroforestry And Reforestation With The Gold Standard - Decision Analysis of A Voluntary Carbon Offset Label

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Abstract

Voluntary standards help to ensure the quality of projects eligible for carbon offsetting, i.e. selling carbon certificates. However, in deciding on whether to adopt such standards the managers of carbon offset projects are faced with uncertainty regarding the costs and risks involved. Decision Analysis provides a helpful set of tools that can support such decisions by forecasting outcomes under different scenarios. We applied Decision Analysis methods to generate models for the decision to certify two projects in Costa Rica with the voluntary carbon offset label *Gold Standard.* We evaluated certifying an additional site of a partially certified reforestation project, as well as the initial certification of an agroforestry project.

We calibrated and interviewed decision-makers and stakeholders of the certification projects to identify important parameters and translated these into a decision model. We ran the final decision model as a Monte Carlo simulation to project plausible ranges of decision outcomes, expressed as Net Present Values and annual cash flows. We identified critical uncertainties and research priorities by using the Expected Value of Perfect Information. The results indicate that certification of the two projects would result in a positive Net Present Value. The partially low return on investment of the certification, however, shows the need for projects to undergo thorough evaluation and generate customized strategies before participating in a voluntary carbon offset scheme. The Decision Analysis approaches we describe can help to improve the process of decision making under uncertainty and should be widely adopted for evaluating the potential impacts of certification.

Introduction

Forests absorb the equivalent of roughly two billion tons of CO_2 each year (FAO, 2018). At the same time, forest loss and degradation are estimated to contribute approximately 12% of annual greenhouse gas emissions globally, making it the second largest anthropogenic source of atmospheric CO_2 (after fossil fuel combustion) (FAO, 2018; van der Werf et al., 2009). As a strategy to mitigate climate change, the Kyoto Protocol’s Clean Development Mechanism (CDM) offers an economic reward for projects that sequester CO_2 and other greenhouse gases (GHG). Emission reductions achieved, e.g. through afforestation and reforestation (A/R) activities, can be sold in the form of carbon certificates, and due to their high CO_2 fixation potential, forests have become an important sector of the global carbon credit market (Bumpus & Liverman, 2008; UNFCCC, 1997). The so-called carbon offsets allow developed economies to meet their emission reduction targets by purchasing carbon credits that are associated with projects in developing economies (UNFCCC, 2007). Parallel to the CDM a Voluntary Carbon Offset Market (VCM) with private actors has emerged, where carbon credits are sold in the form of Verified Emission Reductions (VER), with each VER corresponding to one ton of CO_2 equivalent (Bumpus & Liverman, 2008). Critics have pointed out that the CDM market has many shortcomings (such as too much bureaucracy and a lack of sustainable development co-benefits), which the VCM aimed to address. However, the VCM has also faced criticism, such as a lack of transparency and double-counting of offsets. As a response to the criticism, voluntary carbon offset standards were created in order to standardize the quality of projects eligible for carbon offsetting (Lovell, 2010). One of the most important labels, especially in the forestry and land use sector, is the Gold Standard. It was initiated in 2006 by the World Wide Fund for Nature (WWF) and offers several methodologies under which projects can be certified, including an “A/R GHG Emissions Reduction & Sequestration Methodology” (The Gold Standard, 2017).

When deciding on investments in certification, e.g. with the Gold Standard, project managers are faced with uncertainty. Studies have shown that strong carbon offset certifications like the Gold Standard can increase consumers’ willingness-to-pay for carbon credits and for the co-benefits associated with the certification (Liu et al., 2015; MacKerron et al., 2009). On the other hand, establishing and maintaining the certification of a project often comes with high costs and risks, and little research is available on the overall benefits of certification (Galik & Jackson, 2009). The decision on whether or not to apply for certification, e.g. with the Gold Standard, is therefore influenced by many factors, including the time and effort required to prepare and maintain the certification, the certification fee, the potential additional income or the change in consumer’s perception of the project. Some of these variables are hard to quantify, making the decision about potential certification complex and difficult.

The need to take practical decisions within complex ecological and economic systems is a challenge many decision-makers face. This is particularly the case with silvicultural and agricultural systems, which are characterized by uncertainty and dynamically changing and interacting factors. Decision Analysis provides a helpful set of tools that can support decisions in such complex systems. Together with stakeholders and calibrated experts, the state of knowledge on all processes and input variables is captured, e.g. in the form of probability distributions. The input parameters are translated into probabilistic simulations that predict the full range of plausible outcomes, improving the process of decision-making under uncertainty (Lanzanova et al., 2019; Luedeling & Shepherd, 2016).

In the field of forestry, uncertainty analysis and multi-criteria decision analysis (MCDA) have been applied for a range of applications. Kangas and Kangas (2004) provided a useful theoretical overview with practical examples, e.g. on the management of forests and forest ecosystems (Fürstenau et al., 2007; Rauscher et al., 2000). While most studies aim to reflect the preferences of stakeholders, experts and decision-makers, they often fail to include expert knowledge in cases where data is missing. Instead, the decision process is simplified by excluding relevant factors or by assuming fixed values for variables that are clearly not precisely known. The values assumed in such studies may not be reasonable representations of reality. Research approaches are available that allow studies to work with ranges of probabilities where data is uncertain or missing. Davis and Keller (1997) used Monte Carlo simulations for slope stability prediction in forests. Lähtinen et al. (2008) applied multi-criteria decision analysis to analyze the relative importance of tangible and intangible resources in the forestry industry. Entezari et al. (2020) combined Monte Carlo algorithms with spatial data to facilitate forest inventories.

There is considerable scope for decision analysis methods to be applied in forestry and agricultural management. Luedeling and Shepherd (2016) argue that decision analysis can solve the problem of data gaps and allow explicit consideration of risks and variability in agriculture. Monte Carlo-based decision models (Favretto et al., 2017; Rosenstock et al., 2014) as well as Bayesian network models (Whitney et al., 2018) can help provide robust guidance for decision-making without cost-intensive long-term data collection. In the field of agriculture, decision analysis approaches have been used for many application, e.g. to assess viable investment options in honey value chains (Wafula et al., 2018), the nutritional value of home gardens (Whitney et al., 2017), intervention options to prevent reservoir sedimentation (Lanzanova et al., 2019) or the viability of agroforestry investments (Do et al., 2020).

Several authors have recommended evaluating the individual prerequisites of carbon offsetting projects before taking a decision (ICROA, 2014; Kollmuss et al., 2008). Yet most studies focus on the post-certification impacts rather than on supporting decisions. Many of these studies investigate effects on livelihoods in the communities providing the carbon offsetting (Herr et al., 2019; Lansing, 2015; Lehmann, 2019). Studies that have supported actual decisions on certification by thoroughly evaluating potential certification benefits a priori are rare.

Here we demonstrate the use of decision analysis in the context of voluntary carbon offsetting labels. We used an innovative decision analysis approach to evaluate the prospective benefits of voluntary carbon offset labels for the projects providing the carbon offsetting. We conducted individual interviews and elicited feedback from decision-makers and stakeholders on multiple occasions to appraise the merits of specific certification projects. Through the application of several participatory processes, we developed a comprehensive decision model that included all the aspects that local experts considered important in assessing the impacts of certification. We subjected experts to calibration training, to enable them to provide probability distributions for all input parameters in the form of estimated confidence intervals. We ran the final decision model as a Monte Carlo simulation to project plausible ranges of decision outcomes, expressed as Net Present Values and annual cash flows. We identified critical uncertainties and important variables for further research using model sensitivity and value of information analysis.

We aim to showcase a methodology that can determine whether the positive social, ecological, and economic benefits outweigh the costs and risks involved in establishing and maintaining certification. We demonstrate the application of these methods with a reforestation and agroforestry project in Costa Rica. We focused our decision model to determine whether the positive social, ecological and economic benefits of certification are likely to outweigh the economic expenses of a) certifying an additional reforestation site as a new area within an existing certification scheme, and b) carrying out a new certification process for an agroforestry site.

Materials And Methods

2.1. Study area and setting

Since 2007, the project network FuturoVerde has been engaged in environmental activities in Costa Rica. The two German companies BaumInvest AG and PuroVerde eG are part of the project network, implementing reforestation and agroforestry projects in the Alajuela Province together with their partner companies in Costa Rica (Querdenker GmbH, 2017). BaumInvest AG is an unlisted stock corporation, aiming to combine sustainable reforestation with generating financial returns for the investors (BaumInvest AG, 2018). PuroVerde eG is an association of consumers, traders, and producers who jointly invest in the development, cultivation, and marketing of tropical products from permaculture and forestry (PuroVerde, 2018). Together with their experts and stakeholders we built two simulation models to cover the costs, benefits, risks and uncertainties of two certification decisions for BaumInvest AG and PuroVerde eG.

Decision a) In 2010 BaumInvest AG certified 150 hectares of their reforestation sites with the CarbonFix standard. CarbonFix was purchased by the Gold Standard in 2012 (The Redd Desk, 2014). At present, BaumInvest AG is considering the addition of another 375 hectare within the already existing certification framework according to the “new area” scheme of the Gold Standard (The Gold Standard, 2018).

Decision b) PuroVerde eG plans to extend its currently small ginger production into a much larger agroforestry project. Certifying the agroforestry sites under the “Gold Standard A/R GHG Emissions Reduction & Sequestration Methodology” (The Gold Standard, 2017), the same certification applied to BaumInvest AG’s reforestation sites, could offer additional benefits for PuroVerde eG.

2.2. Decision Analysis approach

The decision analysis method we used is inspired by the Applied Information Economics Approach developed by Hubbard Decision Research (Hubbard, 2014), and research projects conducted by Luedeling et al. (2015), Whitney et al. (2017), and Lanzanova et al. (2019).

A crucial first step in the decision analysis process is to focus on a decision, with precisely formulated alternative options, for which a rational recommendation is to be made (Luedeling & Shepherd, 2016). We defined the decision questions with the research managers of both the agroforestry and the reforestation projects. The decisions were then confirmed by the relevant board members of the companies. In order to assess the current state of knowledge on all uncertain factors involved in the decisions, we conducted a literature review of relevant Gold Standard documents and current research on voluntary carbon offset labels and related topics. A central principle of decision analysis is the inclusion of experts, stakeholders and decision-makers. We therefore conducted several rounds of interviews in Costa Rica and in Germany, each with one or two experts from the project network.

We developed the decision model by working with local experts through several interview and modeling stages (Fig. 1). In a first round of interviews in Germany, we worked with experts to identify relevant factors that could affect the decisions and described the corresponding causal mechanisms. We aimed to consider all aspects of relevance to the decisions, regardless of whether the parameters could easily be measured or modeled. We translated the factors and their relation into a graphical model (Fig. 2). We validated the model and verified and completed the list of input variables in a second round of interviews in Costa Rica. The information retrieved from the interviews and the literature review was then reformulated as a set of equations that reflected as much as possible the experts' and analysts' understanding of the decision. We coded the mathematical models as a first draft of a function in the programming language R (R Core Team, 2018), using several functions from the R package "decisionSupport" (Luedeling et al., 2019). Wherever possible, we used empirical data to generate priors describing the variable values (e.g. for the Gold Standard fees). Where no data were available, placeholders were used for the first run of the model.

For those input parameters for which no empirical data were available, we elicited values from appropriate experts within the project network in both Costa Rica and Germany.

Before value estimates were elicited from the experts, participants were subjected to calibration training, a well-established methodology to raise experts' ability to estimate their own state of uncertainty (Hubbard, 2014). The training included trivia questions and equivalent bet tests. This training raised the experts' capacity in providing reliable ('calibrated') estimates of 90% confidence intervals (i.e., they were 90% confident that the provided range included the correct value) in the form of upper and lower bounds for the variable values (Hubbard, 2014). While calibration training is often carried out with groups of experts (Lanzanova et al., 2019; Luedeling et al., 2015), we conducted it individually. This allowed us to adapt the calibration training to the needs and skills of each person. Furthermore, the individual trainings helped us to manage our time and resource constraints, which did not allow us to hold joint calibration workshops with all experts. We consolidated all calibrated estimates into one single probability distribution for each model parameter (Luedeling et al., 2015). To reconcile variable estimates from multiple experts we aggregated all individual assessments by consensus. This approach aims to overcome the risk of losing important information caused by averaging, an often preferred strategy (Lyon et al., 2015). If no empirical data were available and no experts could be identified (e.g. for the carbon sequestration potential of agroforestry sites), we retrieved the value ranges for the variables from the literature.

Once we had gathered values for all input variables (empirical data, calibrated estimates and value ranges from the literature), we ran the final decision models 10,000 times as a probabilistic Monte Carlo simulation, with each run providing one possible outcome. The decision outcomes were expressed as Net Present Values (NPV) and annual cash flows. The totality of all model runs converted the probabilistic inputs into a probability distribution of outputs that expressed the range of plausible decision results, given the experts' current state of uncertainty.

We conducted a sensitivity analysis to assess the extent to which the various input uncertainties affected the project outcome estimates, i.e. the key uncertainties in the decision-making process of the project. We applied Partial Least Squares (PLS) regression to identify the variables that the decision model outputs were most responsive to. As a metric providing a quantitative estimate of the effect each individual variable has on the decision outcomes projected by the simulation, we used the Variable Importance in the Projection (VIP) score (Luedeling et al., 2015; Luedeling & Gassner, 2012; Wold, 1995). Furthermore, we calculated the Expected Value of Perfect Information (EVPI) to identify priorities for decision-specific research. The EVPI expresses what would be a rational decision-maker's willingness-to-pay to gain access to perfect information (Luedeling & Shepherd, 2016).

Results

3.1. Crediting period and project lifetime

Together with the experts, we identified time-dependent characteristics and processes over the life span of the projects, and integrated them into the model. In accordance with the experts, we assumed that completing the certification of the agroforestry and the reforestation project would take two years. In line with the Gold Standard requirements, we assumed a crediting period of 30 years for the agroforestry project, during which VER can be earned and marketed (The Gold Standard, 2018). We set the simulated project lifetime of the agroforestry project to 32 years. Gold Standard audits, the so-called performance certifications, take place every five years. The Gold Standard fees as well as the time required to maintain the certification (and therefore the model) differ between non-performance certification and performance certification years. After two years of preparation, the reforestation project would be added as a new area to the existing certification scheme in 2022 during a performance certification. Since the crediting period of the already certified reforestation sites ends in 2036, the crediting period of the newly added sites would be 15 years, with a project lifetime of 17 years. Performance-certifications would take place in years 7, 12 and 17 of the project lifetime.

3.2. Marketing strategies

The experts considered several marketing strategies for the VER generated by the agroforestry project to be feasible. Together we defined three marketing strategies and analyzed the outputs of an adapted version of the agroforestry decision model for each option. The generated VER could either 1) be put on hold to sell carbon-neutral agricultural products instead, 2) be sold directly or 3) be passed on to company shareholders, who could either sell the VER or offset their own emissions by putting them on hold.

3.3. Return on investment

3.3.1. Agroforestry project – Marketing strategy 1) Sale of carbon-neutral products

The cash flow analysis of the sale of carbon-neutral products illustrates that substantial initial investments are incurred during the first three years of the project (Fig. 3). Furthermore, only costs are incurred during this time, while no benefits are obtained, as VER can only be sold after completing the certification in year four. Therefore, the median of the 90% CI of the cash flow predicted by the decision model is negative in year one and two, at 13 thousand and 16 thousand EUR respectively. In year three, the highest investment costs are incurred, and the median of the cash flow drops to 265 thousand EUR. Due to the growth of the project area, the number of VER per year increases over the project lifetime and the cash flow grows from a median of 60 thousand EUR in year four to 79 thousand EUR in year 31. Slight declines in the cash flow occur in years 7, 15, 22, 27 and 32, which corresponds to the frequency of the performance certification years we had calculated. From year four until the end of the crediting period, the lower bound of the 90% CI of the cash flow is positive in all non-performance-certification years. In performance-certification years, where additional fees and staff time are required, the lower bounds of the 90% CI (i.e. the 5% quantile) of the cash flow become negative, ranging between -9 thousand EUR in year seven and -4 thousand EUR in year 27. The median of the cash flow range is slightly lower in performance-certification years than in normal years, but still positive (between 50 thousand EUR in year seven and 65 thousand EUR in year 32). While the range between the lower and upper bounds (the 5% and 95% quantiles) of the cash flow is quite narrow in years one and two (difference of 10 thousand EUR), the difference between the bounds is around 220 thousand EUR in the following 30 years.

The NPV of the sale of carbon-neutral products lies within a 90% CI between -230 thousand and 3.4 million EUR, with a median of 848 thousand EUR (Fig. 4). With this marketing strategy for the VER, the chance of a negative NPV, i.e. a loss, is 14%, the chance of gain is accordingly 86% for the project.

3.3.2. Agroforestry project – Marketing strategy 2) Direct sale of VER

Similar to the sale of carbon-neutral products, the strategy to directly sell the VER has high investment costs before the start of the crediting period and high marketing costs in year three. The initial costs are reflected in the negative cash flow in the first three years of the project lifetime (Fig. 3). For the direct sale of VER, the median of the 90% CI of the cash flow is -13 thousand, -16 thousand and -325 thousand EUR in year one, two and three, respectively. The increasing median of the cash flow range reflects the increasing number of VER that are generated through the growth of the project area, showing similarities to the sale of carbon-neutral products. After year three, the median of the cash flow increases slightly from around 57 thousand EUR in year four to 70 thousand EUR in year 31 and is positive in all non-performance-certification years. In the performance-certification years, the cash flow ranges between 46 thousand EUR in year seven and 57 thousand EUR in year 32 (end of the crediting period). The difference between the lower and upper bound of the cash flow is 10 thousand EUR in year one and two. From year three on, the difference between the lower and upper bound of cash flow fluctuates around 21 thousand EUR, similar to the sale of carbon-neutral products.

The NPV of the direct sale of VER lies, with 90% confidence, between -342 thousand and 3.2 million EUR, with a distribution median of 687 thousand EUR (Fig. 4). While the upper bound is similar to the sale of carbon-neutral products, the lower bound and the median of the NPV of the direct sale of VER are slightly lower than for the sale of carbon-neutral products. The chance of a loss is 20% for the project, if the direct sale of VER is chosen.

3.3.3. Agroforestry project – Marketing strategy 3) Pass VER on to company shareholders

The cash flow of the strategy to pass the VER on to company shareholders is negative in the first two years of the project, with a median of the 90% CI of -13 thousand EUR in year one and -16 thousand EUR in year two, similar to the sale of carbon-neutral products and the direct VER sale (Figure 3). The positive median of the cash flow in year three (28 thousand EUR) reflects the lower initial investment costs (especially in the area of marketing) of passing VER on to the shareholders, compared to the other two strategies. Unlike when selling carbon-neutral products or the VER directly, the median of the cash flow range of passing the VER on does not increase after year three, but stabilizes around 51 thousand EUR, slightly lower than the median of the other two marketing strategies. As neither VER nor carbon-neutral products are sold, the increase of the certified area does not generate an income increase over the lifetime of the project. The median of the 90% CI of the cash flow declines slightly in performance-certification years. It lies around 37 thousand EUR in year 7, 12, 17, 22, 27 and 32. The difference between the lower and upper bound of the 90% CI is around 10 thousand EUR in years one and two and fluctuates around 200 thousand EUR from year three until the end of the project lifetime. The 90% CI for the cash flow from year three onwards is considerably wider than the ranges of the other two strategies.

The NPV of the marketing strategy of passing VER on to company shareholders had a 90% CI between -130 thousand and 3.2 million EUR, with a median of 783 thousand EUR (Fig. 4). When passing VER on to the shareholders, the chance of a loss is 13% for the project.

3.3.4. Agroforestry project – Comparison of the three VER marketing strategies

In case of the Gold Standard certification of the agroforestry project, the NPV distributions of all three VER marketing strategies have positive medians that do not differ significantly (Fig. 4). The sale of carbon-neutral products, however, has a slightly higher median than both the direct sale of VER and passing them on to the company shareholders. The probabilities of a net loss when selling carbon-neutral products and passing VER on to shareholders are quite similar, while the direct VER sale has a slightly higher risk of a negative NPV. The direct sale of VER has the highest investment costs of all three strategies, showing the lowest median of the cash flow range in year three. The median of the cash flow range of the sale of carbon-neutral products also reaches its low point in year one, but is slightly higher than the direct VER sale option. Passing the VER on to the company shareholders is the strategy with the lowest investment costs. The low median cash flow (achieved in year two) of passing the VER on to the shareholders is higher than in the other two strategies (not achieved until year three) (Fig. 3).

3.3.5. Reforestation project

The cash flow range of the reforestation project (Fig. 5) reflects the low initial investment costs and shows a positive median in year one (nine thousand EUR) and year two (eight thousand EUR). In year three marketing and communication costs are incurred, and the certification process is completed. VER from the three previous years can be sold in addition to the VER generated in the year of the certification due to a retroactive issuance scheme of the Gold Standard (The Gold Standard, 2018). The cash flow is therefore clearly positive in year three. The median of the 90% CI of the cash flow is 127 thousand EUR in year three, the highest median throughout the project lifetime. The median of the cash flow remains positive in all non-performance-certification years, with negative values occurring in the performance-certification years seven (-10 thousand EUR) and 12 (-12 thousand EUR). In the last performance-certification year (year 17), the median of the cash flow range is one thousand EUR. Throughout the years of the project lifetime, the cash flow range shows high variability, reflecting the harvest and reforestation cycles of the reforestation site, which change the number of available VER. In non-performance-certification years, the median of the cash flow range decreases from 28 thousand EUR to one thousand

EUR between year four and year 11, then increases to 17 thousand EUR in year 13 before decreasing again to 15 thousand EUR in year 16.

The NPV of the certification for the reforestation project lies with a 90% CI between -29 thousand and 750 thousand EUR, with a median of 252 thousand EUR (Fig. 6). The chance of a negative NPV, i.e. a loss, is 7% in case of the certification of the reforestation project.

3.4. Sensitivity analysis

3.4.1. Agroforestry project – Marketing strategy 1) Sale of carbon-neutral products

Sensitivity analysis indicated that three variables had an important effect on the outcome of the simulation (NPV and cash flow) in case of the Gold Standard certification of the agroforestry project with marketing strategy 1) “Sale of carbon-neutral products”. Variables are commonly considered important when their VIP values exceed 0.8 (Luedeling & Gassner, 2012). The variable “Additional shares sold”, an indirect benefit of the certification, has the highest VIP of all variables, with a score of 4.2 (Fig. 7). The impact of using the generated VER to create carbon-neutral products is reflected in the VIP of the variable “additional product sales”, which has a score of 1.17. The last variable with an important effect on the outcomes is the “discount rate”, although its VIP score of 0.95 lies only slightly above the threshold of 0.8. For the direct sale of VER, “Additional shares sold” is the only variable with a non-zero EVPI in case of project implementation (Fig. 7). The EVPI of the variable is two thousand EUR which corresponds to the decision-maker’s rational willingness-to-pay to obtain perfect information on the variable.

3.4.2. Agroforestry project – Marketing strategy 2) Direct sale of VER

Three input variables are considered important for the outcome of the direct sale of VER. Similar to the sale of carbon-neutral products, the variable “Additional shares sold”, an indirect benefit of the certification, has the highest impact on the outcome of the simulation, with a VIP score of 4.28 (Fig 7). The VIP score of “Carbon dioxide sequestration” is 0.86, indicating that the direct certification benefits of being able to sell the generated VER have an important, but much smaller impact than the indirect benefits. The third variable considered important is the discount rate, with a VIP score of 0.83. “Additional shares sold” is the only variable with a non-zero EVPI in case of the implementation of a Gold Standard certification with marketing strategy 2) “Direct sale of VER” (Fig. 7). The EVPI of the variable is nine thousand EUR.

3.4.3. Agroforestry project – Marketing strategy 3) Pass VER on to company shareholders

Marketing strategy 3) “Pass VER on to company shareholders” is primarily focused on the indirect benefits, as the VER are neither sold nor used for carbon-neutral products, but given to the shareholders. This approach is reflected in the VIP score of 4.4 of the variable “Additional shares sold” (Fig. 7). It is the only variable with a VIP score above 0.8 for passing the VER on. Similar to the sale of carbon-neutral products and the direct VER sale “Additional shares sold” is the only variable with a non-zero EVPI (Fig. 7). The variable has an EVPI of three thousand EUR.

3.4.4. Reforestation project

Sensitivity analysis indicated that the output of the model was sensitive to the variables “VER price” (VIP = 3.422) and “additional stock sales” (VIP = 2.393). The two variables reflect the impact of both the direct and the indirect benefits of the certification (Fig. 8). The VER price is related to the benefits from the direct VER sales, while the additional stock sales are the indirect outcome of the impact the certification has on the shareholders’ willingness to purchase shares. The only variable with a non-zero EVPI was “VER price”. The calculation indicates that the decision maker should be willing to pay three thousand EUR to know more about the effect of this variable on the decision outcome (Fig. 8).

Discussion

4.1. Return on Investment

4.1.1. Agroforestry project – Comparison of the three VER marketing strategies

Model results suggest that all three VER marketing strategies for a Gold Standard certification of the agroforestry project are likely to lead to additional profit. For all strategies the chance of loss when investing in certification is lower than the chance of opportunity losses of operating without certification. Implementing the certification with one of the strategies therefore seems sensible. The choice of VER marketing strategy depends on the priorities and preferences of the decision-makers. While establishing a preference between the sales of carbon-neutral products and passing the VER on to the company shareholders, the direct sale of VER clearly emerged as the least advisable. The direct sale of VER has the lowest median NPV, the highest probability of loss and no clear advantages compared to the other two strategies. A key reason for the low benefits of direct VER sale might be the low carbon sequestration potential of agroforestry projects compared to forestry projects (FAO, 2016). The low additional income of directly selling VER confirms the importance of evaluating a project’s specific setting before considering a particular certification scheme, mirroring conclusions drawn in many earlier studies (Fischer et al., 2017; Hamrick & Gallant, 2017; Kollmuss et al., 2008; Tienhaara, 2012). Most studies that have analyzed the framework of carbon offsetting see potential economic benefits for participating projects, but also acknowledge the scarcity of empirical studies on the actual impact on these projects (ICROA, 2014; Kollmuss et al., 2008).

Both the sale of carbon-neutral products and passing VER on to company shareholders have certain advantages. Selling carbon-neutral products seems to have the highest return on investment in the long run, as it has the highest median NPV, and the lowest probability of loss. The positive return on investment confirms the results of several studies that report a high willingness-to-pay for carbon labeled products among consumers, which led to an overall positive impact on company incomes (Feucht & Zander, 2018; Kim et al., 2016; Vecchio, 2013; Vecchio & Annunziata, 2015). An applied example of the sale of carbon-neutral products is the Gold Standard-certified company ForestFinest, which puts VERs generated by their cocoa tree plantations on hold to produce “climate positive” chocolate (Sommer-Guist & Assenmacher, 2015). The NPV and the probability of gain are slightly lower for passing VER on to shareholders than for the sale of carbon-neutral products. A clear advantage of passing the VER on to shareholders are the significantly lower investment costs in year three, a result of the lower marketing costs (compared to the direct sale of VER and carbon-neutral products). This is particularly important, as low liquidity during the initial years is a challenge for the agroforestry project.

4.1.2. Reforestation project

The outcome of the decision model for the reforestation project (a low probability of loss and a positive median NPV) suggests that a Gold Standard certification of the reforestation sites would lead to additional benefits for the reforestation project. The chance of loss when investing in certification (7%) is lower than the chance of opportunity losses of operating without certification. It is therefore advisable for the reforestation project to make the investment. The additional income for the project confirms the potential of certifying reforestation projects that many studies have identified (ICROA, 2014; Kollmuss et al., 2008; Wright et al., 2000). The clearly positive cash flow during the first six years after the initial certification could contribute to closing the current liquidity gap that poses a challenge for the company. The potential negative cash flow in performance-certification years would, however, have to be compensated by other income sources of the company. Another concern is the decrease in cash flow from year six until the end of the crediting period due to the decreasing VER sales. Low replanting rates after harvests in the current management plan cause decreases in carbon sequestration, reducing the amount of VER available for sale. Revising the current management and replanting scheme for the reforestation project could help to reduce the decline in carbon sequestration, and thus positively affect the cash flow.

4.2. Sensitivity analysis

4.2.1. Agroforestry project – Comparison of the three VER marketing strategies

The high VIP score and non-zero EVPI for all strategies indicate that the variable “Additional shares sold” is the most important across the marketing strategies of the agroforestry project. The high importance of the additionally sold company shares implies that the indirect benefits arising from the certification have a greater influence on the outcomes than the direct benefits. The low CO2 sequestration potential of agroforestry sites compared to forests, however, could be an explanation for the low importance of the VER sales even when sold directly (FAO, 2016).

The value range for the additionally sold company shares was set quite widely in the process of estimating the input variables, as little knowledge about the impact of certification on the company shareholders was available. The high importance of the variable and the initially wide range are reflected in the EVPI, which ranked between 1.9 thousand and 7.3 thousand EUR for the three strategies. The decision-makers’ rational willingness-to-pay to gain more knowledge on the variable is low compared to the overall value of the decision. Even a small investment between 1.9 thousand and 7.3 thousand EUR could however help to increase certainty regarding the decisions. For example, conducting a survey among the current shareholders would be a simple way to obtain additional information on the effect that the Gold Standard certification would have on current and potential new shareholders. Gaining more knowledge, e.g. on the additionally sold company shares, would be beneficial for all of the marketing strategies, and could even help to make a better-informed choice between the three options.

4.2.2. Reforestation project

While the two variables “VER price” and “Additional stock sales” can be considered important for the certification of the reforestation project (according to their VIP scores), only the VER price has a non-zero EVPI. The high importance of the VER price for the reforestation project corresponds to studies that see this variable as a major uncertainty factor for the whole VCM (Lang et al., 2018). Although the variable’s EVPI of 3.5 thousand EUR is low compared to the overall value of the intervention, it is questionable whether more reliable information about this variable can be obtained at all. The VER price is highly volatile and strongly dependent on international policy-making. Predicting its future development with greater certainty is therefore challenging and resource-intensive, and it may well be impossible. Given that the information value is relatively low, decision makers of the reforestation project may still be able to make a fairly confident decision on the best investment option already based on model results with the current state of knowledge.

4.3. Methodological limitations

There is no guarantee that the model accurately captured all important aspects of the possible certification. While group workshops with all important stakeholders at once can be helpful when consolidating input parameters (Whitney et al., 2018), only individual interviews were possible in our research. However, differences in the experts’ inputs mainly concerned the impact of the certification on managing the reforestation areas, and could mostly be resolved by consulting Gold Standard guidelines. Nevertheless, several interviewed staff members of the project network were not familiar with the Gold Standard certification and may have missed implications that certification could have. Although we did our best to complement the interviews with background literature, some variables may still be missing in the model. The model that emerged after several rounds of reviews nevertheless appeared quite comprehensive to all experts, and it included variables and indirect benefits that are often omitted in conventional cost-benefit analyses (Hubbard, 2014). The high importance of the indirect benefits of certification (e.g. the impact on shareholders), which was revealed by the sensitivity analysis, is an indication of the advantages of probabilistic decision analysis.

A common concern about decision analysis is the ability of stakeholders to accurately estimate probability distributions for uncertain variables. Due to time and resource constraints, we did not provide in-depth calibration training that would meet the full recommendations of decision analysts (Hubbard, 2014). However, our use of individual interviews might have helped to avoid typical biases of group interviews, such as anchoring effects (Kahneman, 2011).

Some variables remained difficult to estimate, even with extensive calibration training. Although we encouraged the experts to provide wide ranges whenever they were highly uncertain, they may still have been wrong in some cases. When retrieving values from the literature, we attempted to depict the range of all values found, but a certain risk of missing sources with values outside the ranges remains. However, we are confident that most estimates from literature and experts were accurate.

Given the context under which we designed the decision model, it is difficult to evaluate the impacts of any potentially missing variables or inaccurate estimates. The model describes a situation that has not arisen yet, which means that there is no observed data for validation. Even in the future, validating the model will remain difficult, as the model produces a wide range of possible outcomes. The decision on certification of the reforestation and the agroforestry projects may therefore have a wide range of outcomes without falsifying the model. However, the idea of decision analysis is not to provide a perfect prediction of an intervention's outcome, but to improve the information based on which decision makers act (Luedeling et al., 2015). Even though the model remains, as every model, an imperfect and possibly incomplete reflection of reality, we used a structured analysis process and improved the decision makers' current state of knowledge rather than dismissing relevant variables as unimportant or unpredictable.

Conclusion

We successfully applied decision analysis approaches to develop and apply a comprehensive model simulation to support certification decisions in an agroforestry and a reforestation project in Costa Rica. Involving stakeholders as experts in this process allowed the generation of a realistic simulation that could provide realistic guidance on the prospective net benefits of applying a Gold Standard certification. Our case study confirms that voluntary carbon offset labels can positively contribute to the liquidity of projects providing carbon credits. For both the agroforestry and the reforestation project, we found a positive return on investment for certification with the Gold Standard. However, in comparison to other marketing strategies (selling carbon-neutral products and passing the VER on to shareholders), direct VER sales generated low additional income for the agroforestry project. These low income prospects highlight the importance of ex-ante cost-benefit assessments before applying for certification. Furthermore, developing and analyzing individual marketing strategies for VER is especially important for agroforestry projects. While directly selling VER can be a good option for reforestation projects, our analysis indicates that direct VER sales may not guarantee the highest economic benefits for agroforestry projects. Our work offers a practice-oriented, innovative approach to assess the return on investment of certification with a voluntary carbon offset label.

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Figures

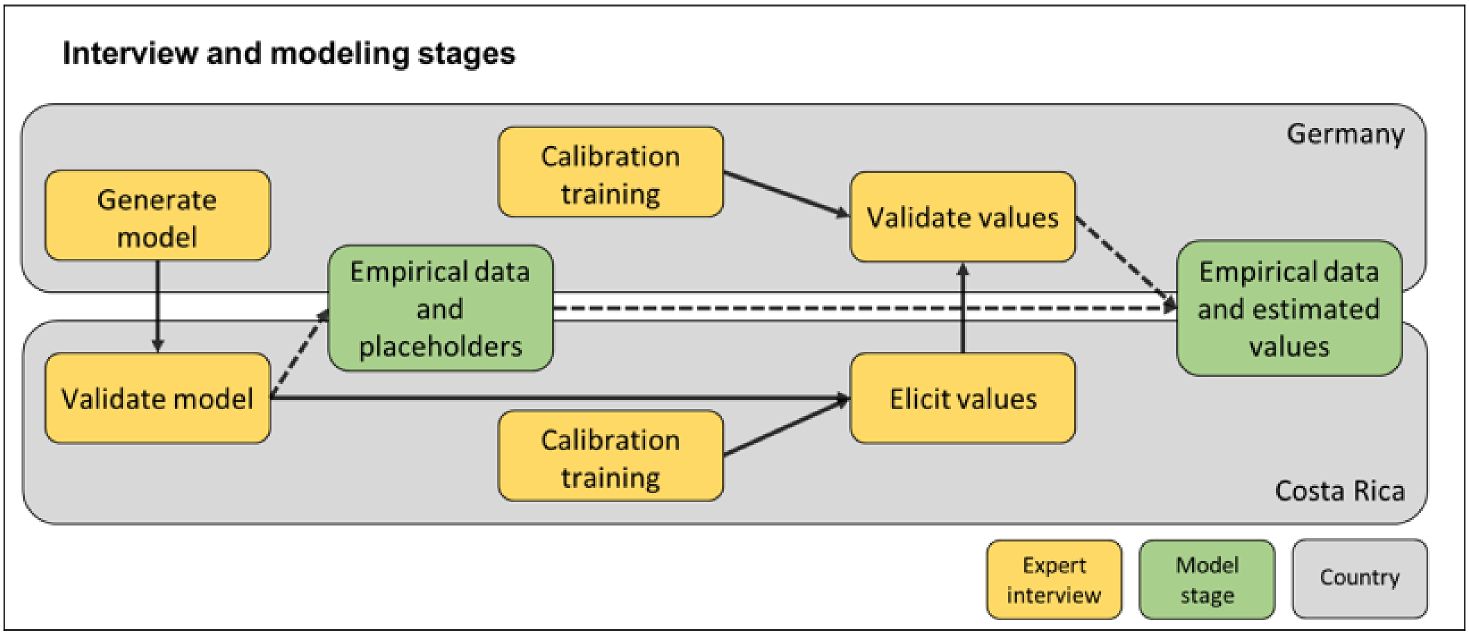

Figure 1

Interview and modeling stages for the development of a decision model for the decision to certify a reforestation and an agroforestry project in Costa Rica with the voluntary carbon offset label Gold Standard.

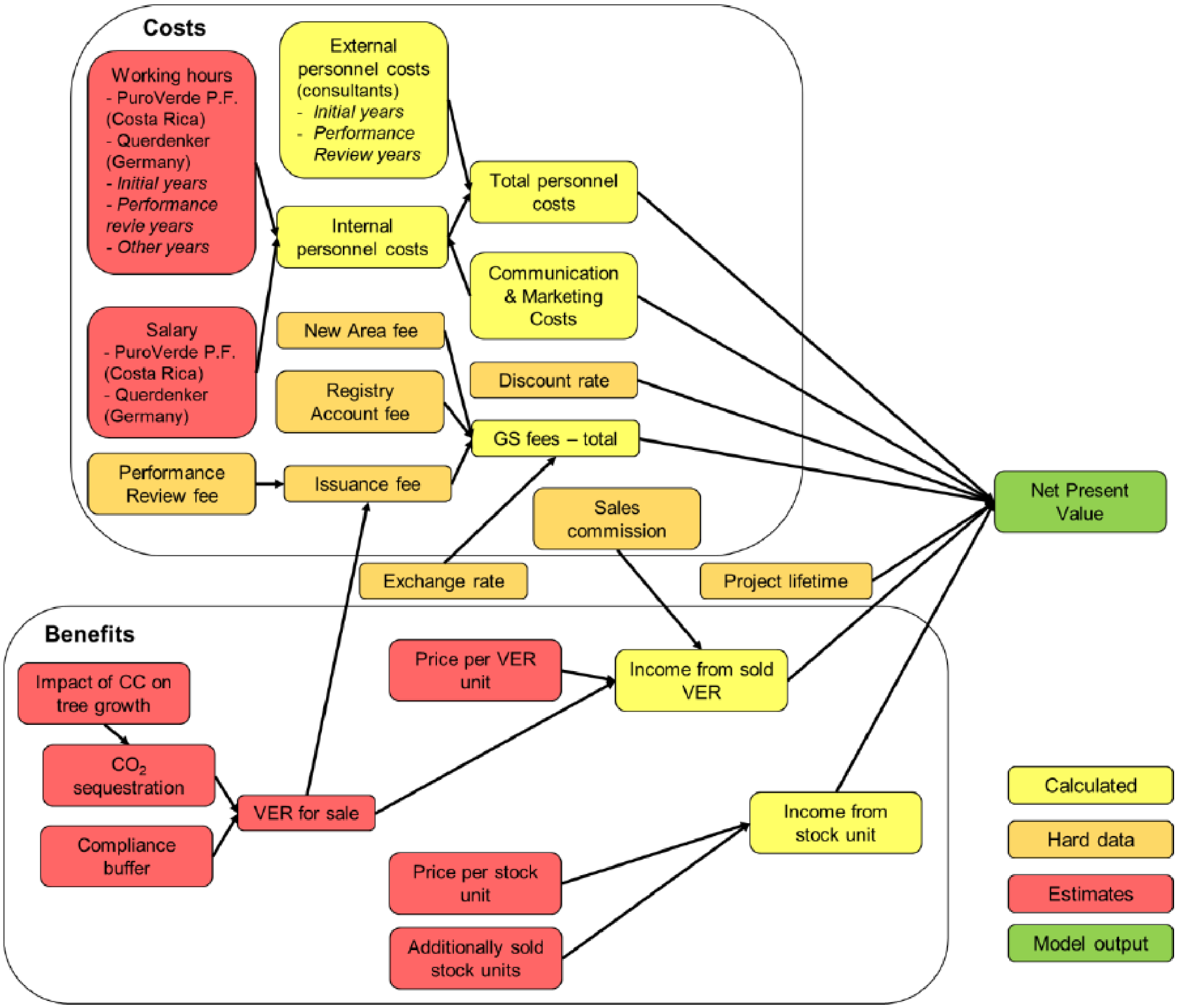

Figure 2

Input variables and overall model structure for the decision analysis of certifying a reforestation project in Costa Rica with the Gold Standard (GS) and selling Verified Emission Reductions (VER) under the impact of climate change (CC).

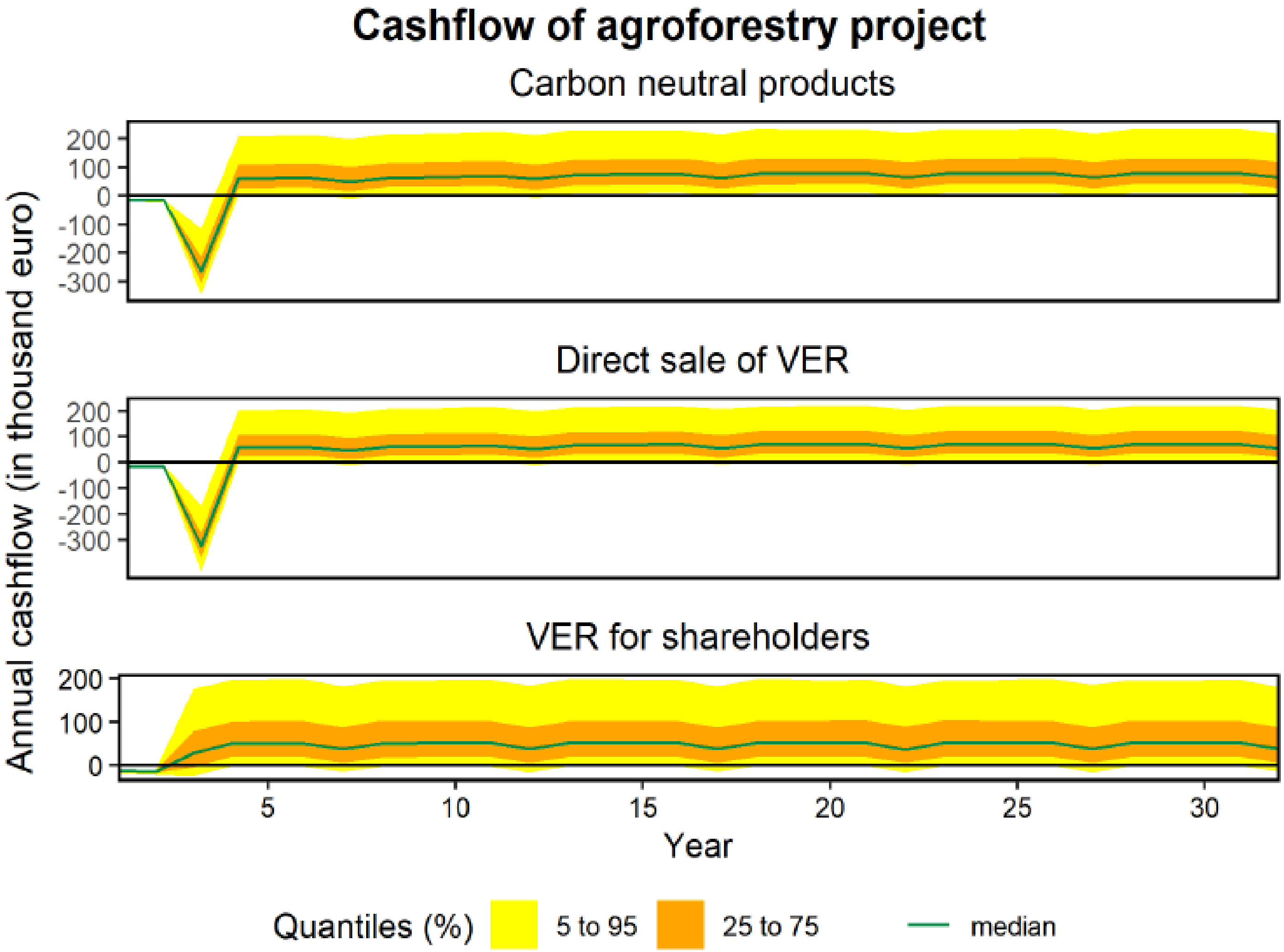

Figure 3

Cash flow outputs of a Monte Carlo simulation (with 10,000 model runs) for ex-ante analysis of the decision to certify an agroforestry site in Costa Rica with a voluntary carbon offset label, with three marketing strategies: 1) Sale of carbon-neutral products, 2) Direct sale of Verified Emission Reductions (VER), 3) Pass VER on to company shareholders. Plots show the projected probability distributions of the annual cash flows.

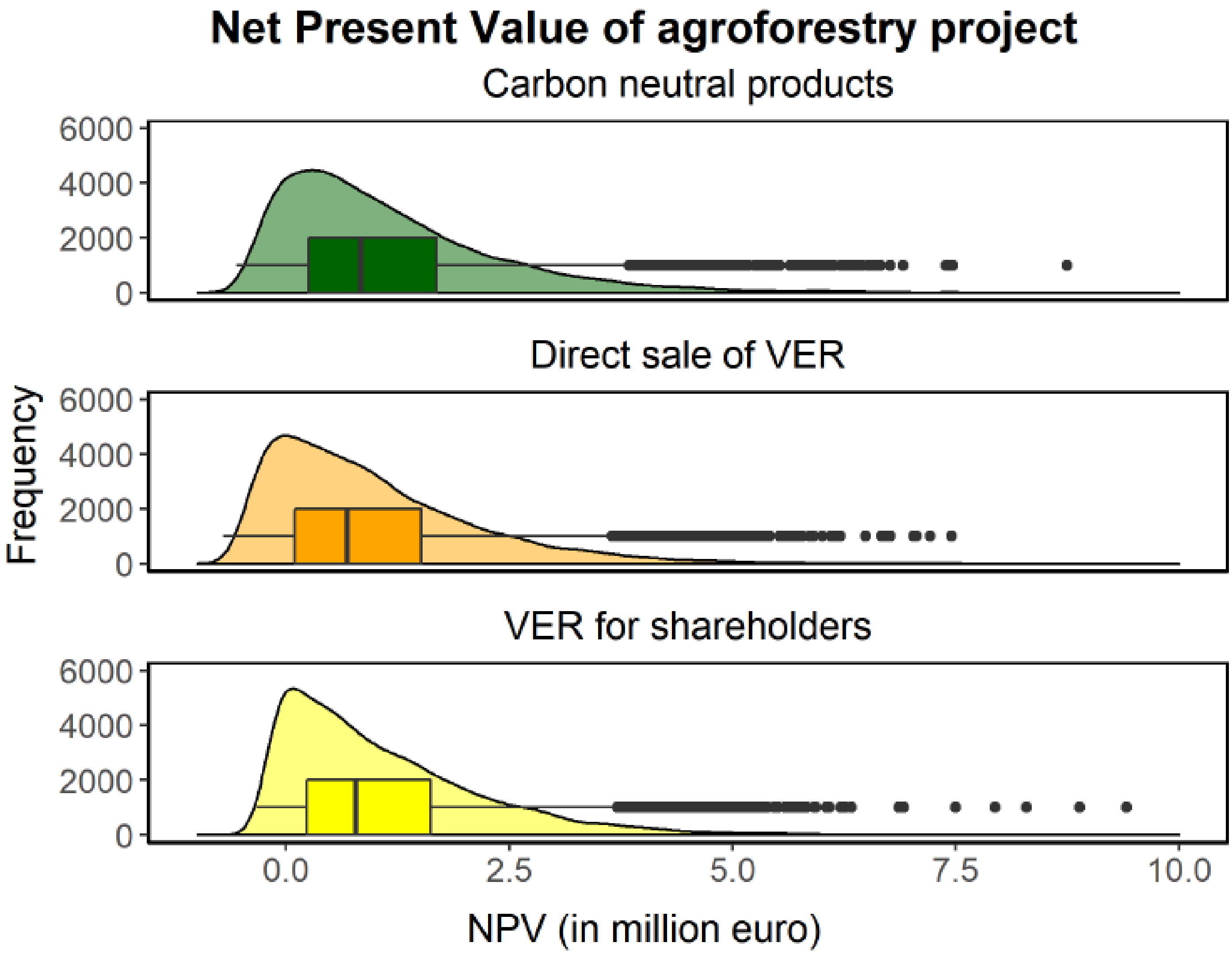

Figure 4

Outputs of a Monte Carlo simulation (with 10,000 model runs) for ex-ante analysis of the decision to certify an agroforestry site in Costa Rica with a voluntary carbon offset label, with three marketing strategies: 1) Sale of carbon-neutral products, 2) Direct sale of Verified Emission Reductions (VER), 3) Pass VER on to company shareholders. Plots show the projected probability distribution of the Net Present Value (NPV) across all the simulation runs. The boxplot indicates the median, 25% and 75% quantiles and outliers of those results.

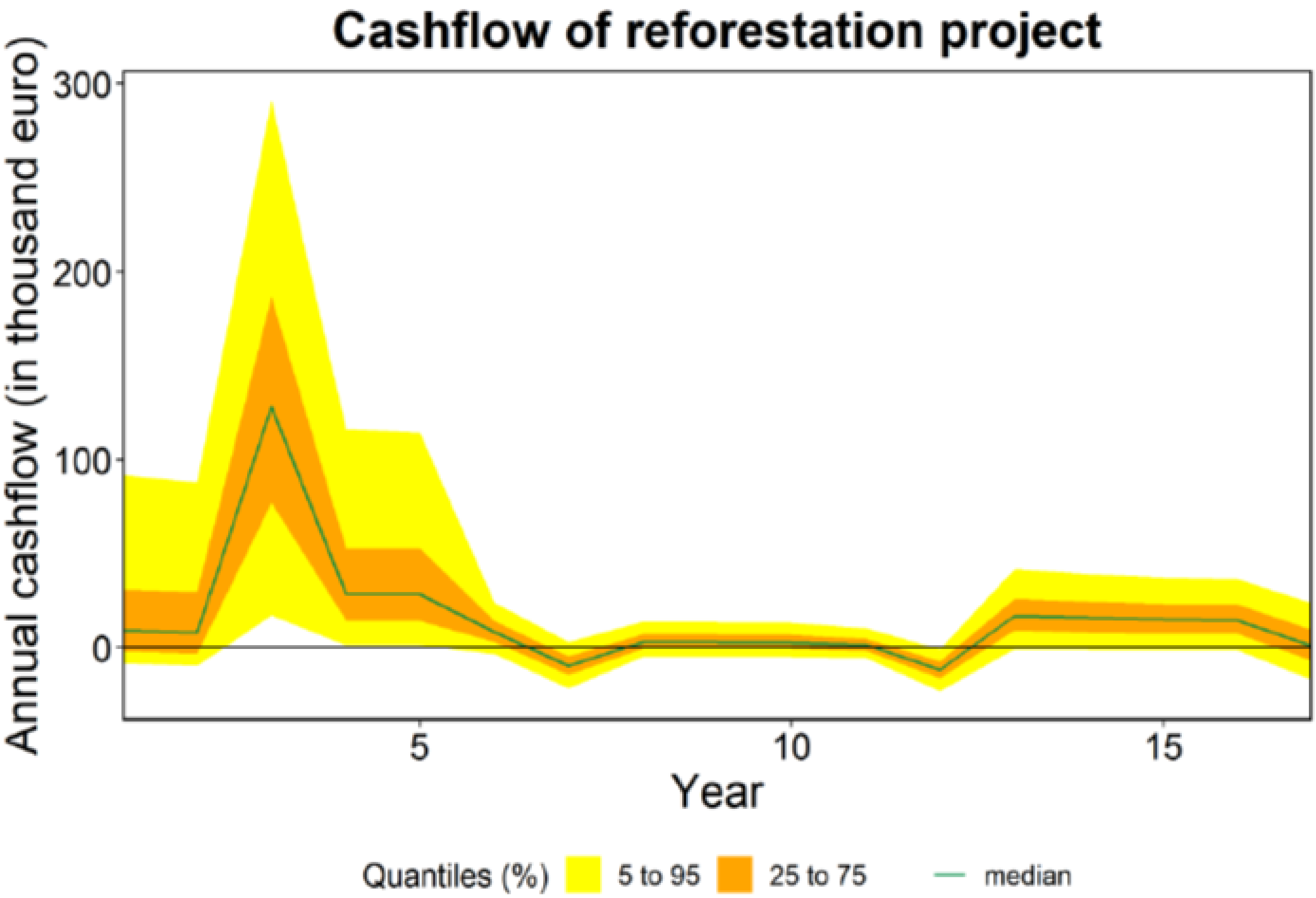

Figure 5

Outputs of a Monte Carlo simulation (with 10,000 model runs) for ex-ante analysis of the decision to certify a reforestation site in Costa Rica with a voluntary carbon offset label. The plot shows the projected probability distribution of the annual cash flow.

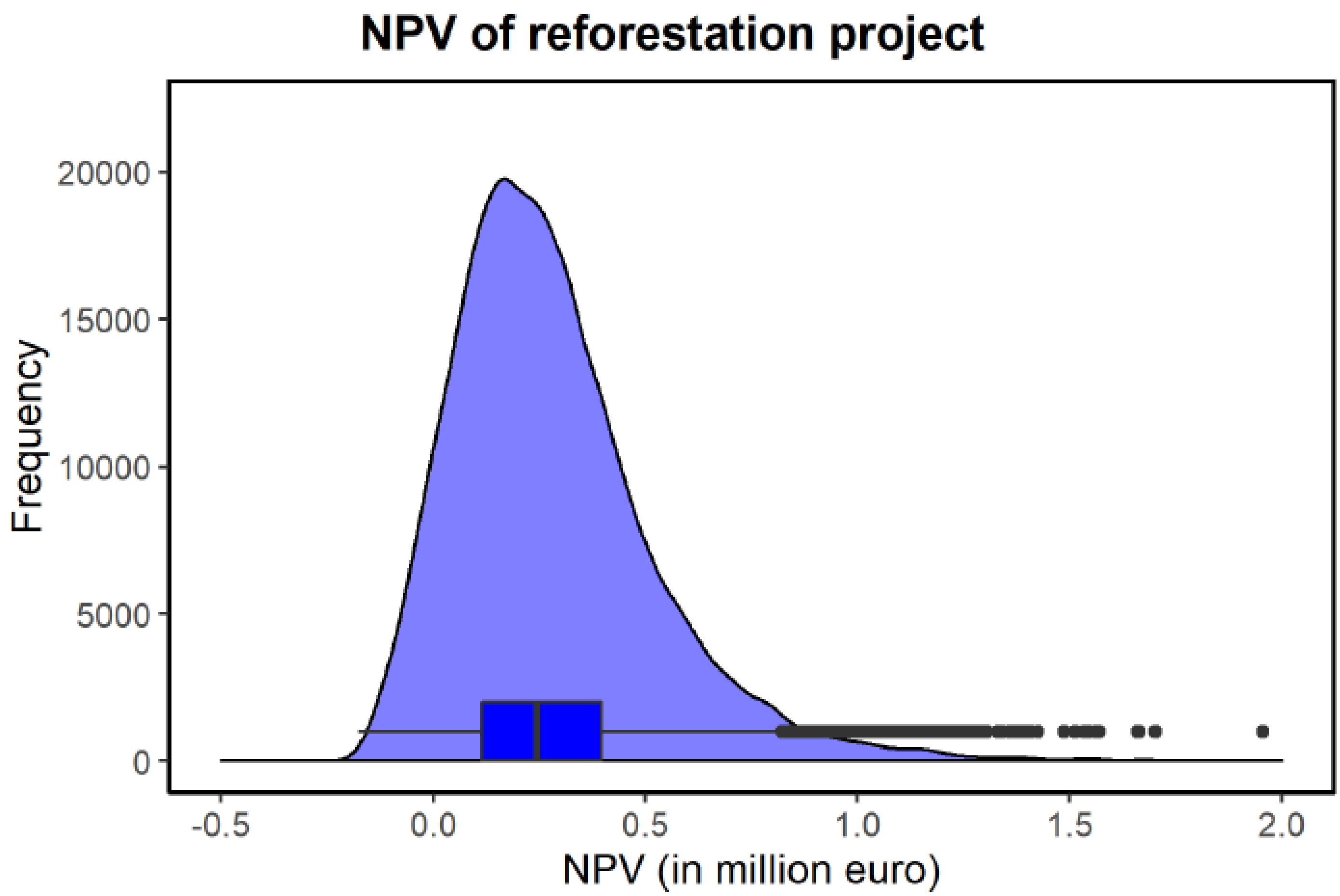

Figure 6

Outputs of a Monte Carlo simulation (with 10,000 model runs) for ex-ante analysis of the decision to certify a reforestation site in Costa Rica with a voluntary carbon offset label. The plot shows the projected probability distribution of the Net Present Value (NPV) across all the simulation runs. The boxplot indicates the median, 25% and 75% quantiles and outliers of those results.

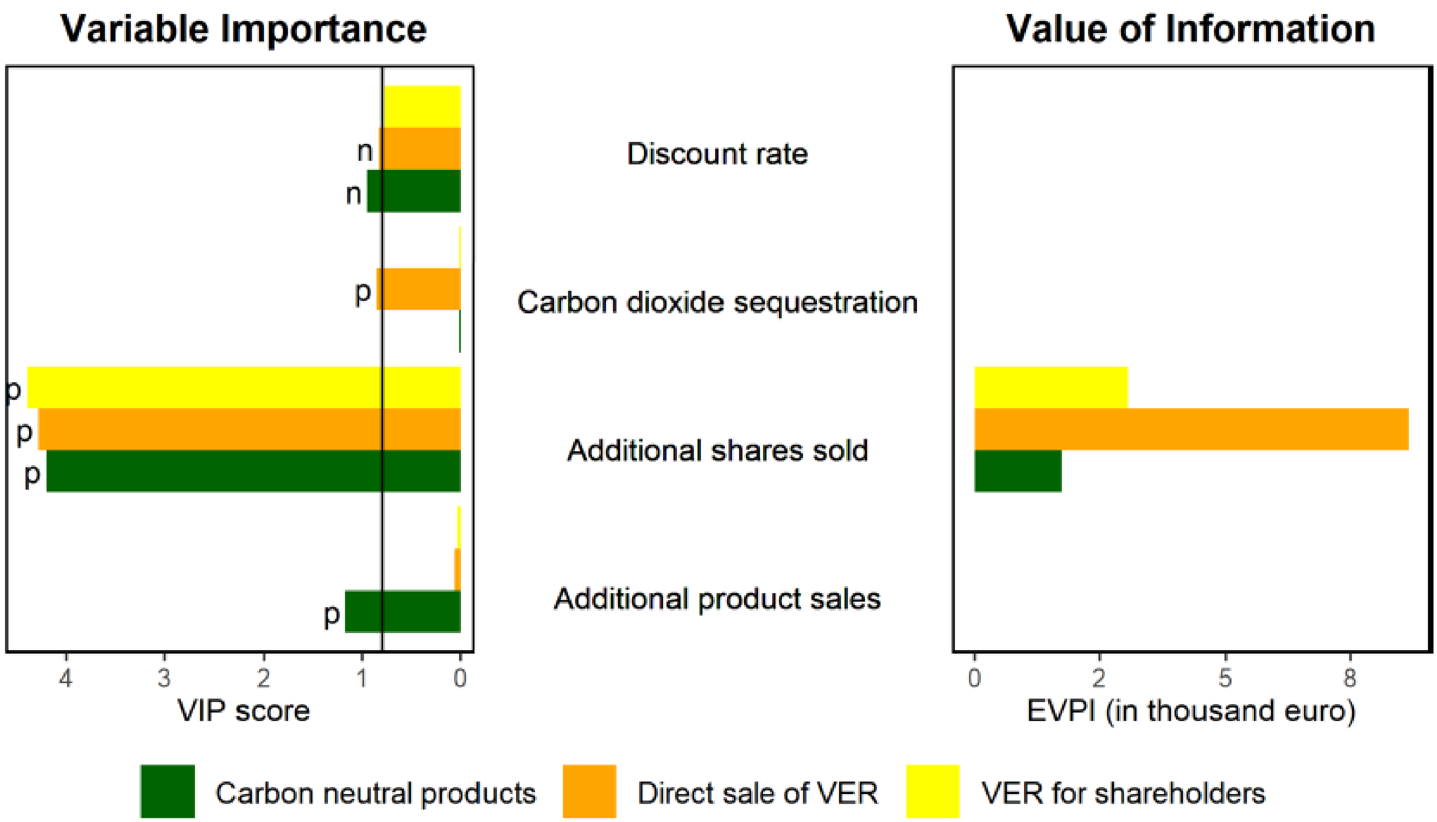

Figure 7

Expected Value of Perfect Information (EVPI) and Variable Importance in the Projection (VIP) for the outputs of a Monte Carlo simulation (with 10,000 model runs) for ex-ante analysis of the decision to certify an agroforestry site in Costa Rica with a voluntary carbon offset label, with three marketing strategies: (1) Sale of carbon-neutral products, 2) Direct sale of Verified Emission Reductions (VER), 3) Pass VER on to company shareholders. The plot on the left shows the Variable Importance, i.e. the sensitivity of projected outcomes to uncertain input variables, quantified by the VIP statistic of Partial Least Squares regression. Only variables with VIP score >0.8 for at least one strategy are shown. Letters indicate positive (p) and negative (n) impact for variables with VIP score >0.8. The right plot shows the EVPI, the amount that the decision maker should be willing to pay in order to improve her certainty about the decision to implement the certification scheme.

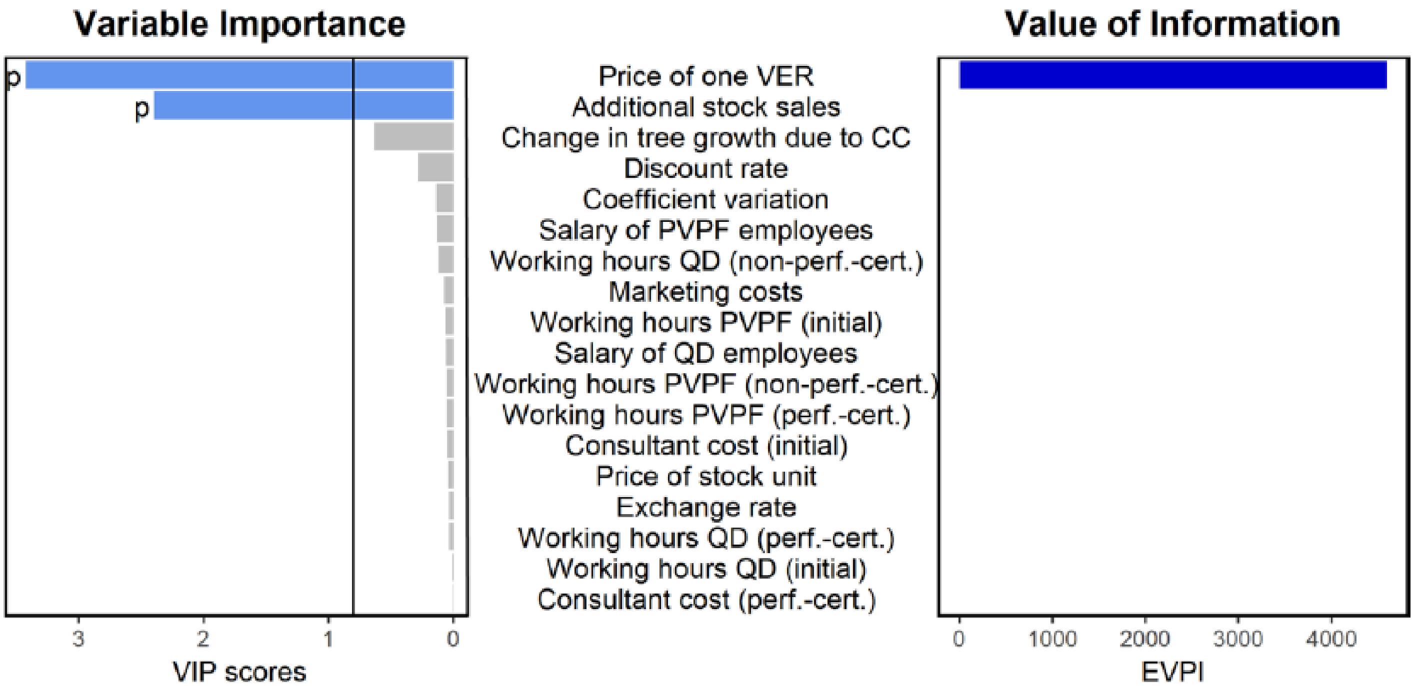

Figure 8

Expected Value of Perfect Information (EVPI) and Variable Importance in the Projection (VIP) for the outputs of a Monte Carlo simulation (with 10,000 model runs) for ex-ante analysis of the decision to certify a reforestation site in Costa Rica with a voluntary carbon offset label. The plot on the left shows the Variable Importance, i.e. the sensitivity of projected outcomes to uncertain input variables, quantified by the VIP statistic of Partial Least Squares regression (blue: VIP>0.8, grey: VIP<0.8). Letters indicate positive (p) impact for variables with VIP score >0.8. The right plot shows the EVPI, the amount that the decision maker should be willing to pay in order to improve his certainty about the decision to implement the certification scheme. VER = Verified Emission Reductions, CC = climate change, PVPF = Puro Verde Paraíso Forestal, QD = Querdenker.