[Prioritisation of adaptation in the development context: Rwanda]

Key Messages

- Standard economic decision support tools either assume future outcomes are known with certainty or assign probabilities to these future outcomes to evaluate the “expected” outcome. However, in data-constrained settings – as often in developing countries – such information may not be available at the necessary level of detail and accuracy.
- Portfolio analysis offers one way of circumventing this problem: it allows to evaluate investments into different portfolios of options, in order to identify the portfolio(s) that yield the highest return for a given level of risk. In this case study of tea plantation in Rwanda, the options considered are different altitude bands in which new tea plantations can be established (geographical choice). Portfolios are the different combinations of these options (altitude bands) that investors can choose to form their “plantation portfolio”.
- With climate change, the yield and price of a tea plantation in a given altitude band is likely to change. The optimal altitude band for planting tea in a scenario without climate change may therefore be suboptimal in a future scenario with climate change. Climate risk mapping is a form of information that can help to anticipate the effects of climate change, thereby changing the plantation portfolio chosen by the tea investors, and thus securing higher yields under scenarios of climate change.
- While the expected benefits of improved information on climate impacts is subject to substantial uncertainties, this study presents evidence of positive returns to climate risk mapping across a wide range of these uncertainties. Even in the “worst-case scenario” that no climate change materialises, there is a positive financial and economic return on the investment into climate risk mapping. In the scenario with climate change, the returns to climate risk mapping are just over 20 times greater.

Context

Standard economic decision support tools, including cost-benefit analysis and cost-effectiveness analysis, either assume future outcomes are known with certainty or assign probabilities to these future outcomes to evaluate the “expected” outcome. These decision support tools attempt to identify the “optimal” choice from a set of options. However, climate change is characterised by deep uncertainty because of the complex interactions between human and biophysical systems. Therefore, standard economic decision support tools may not be suitable for informing decisions that account for climate change.

This document presents insights from a case study on adaptation in tea and coffee farming in Rwanda, and specifically the expansion of plantations. As part of mainstreaming climate change into the tea expansion plans, the study investigated investments into updated tea expansion maps and climate risk maps that show areas suitable for growing tea in both current and possible future climates.

This case is of particular relevance due to the longevity of the assets in question, in this case tea and coffee plantations. They are similar to infrastructure investments with large sunk costs and can remain economically viable for over 50 years. Decisions about the location and layout of new plantations are therefore well advised to consider the impacts of climate change. Yet, due to the lack of detailed climate scenarios with a sufficient spatial and temporal resolution, this decision has to be taken under fundamental uncertainty.

Policy and methodological developments

The decision support tools used in this study have been chosen to reflect the level of uncertainty and the type of adaptation options. Cost-benefit scenario analysis is used to evaluate different adaptation options that address the adaptation deficit in the tea and coffee sectors, for a range of plausible (short-term) future climate scenarios. While the analysis of different measures is carried out at the farm level, there is also the near-term problem of choosing where to implement new tea plantations (climate-smart planning). Portfolio analysis serves to evaluate the investment into climate risk mapping. The results from these decision support tools for the different adaptation investments are then combined to evaluate the overall outcome of a programme for expanding tea and coffee farming.

As climate data in Rwanda is limited (Jones et al., 2015), "light-touch" versions of these decision support tools have been developed. Probabilities are not used to weight the likelihood of outcomes in different climate scenarios (full uncertainty). This case study recognises that traditional cost-benefit and portfolio analysis require probabilities to provide expected returns, but it is hoped that this modification will allow this decision support tools to be used more widely used in contexts where climate information is limited.

The case study uses extensions of the normal economic decision support tools. Instead of evaluating the "optimal" choice for one climate scenario, these decision support tools recommend options that are "robust" in the face of deep uncertainty about how the future climate might change. The decision criteria used in this study are the financial internal rate of return and economic efficiency (measure as the Net Present Value and the Benefit-Cost-Ratio). These criteria are tested for multiple investments across different future climate scenarios.

The **climate scenarios** underlying the analysis are spelled out in terms of temperature and rainfall. For temperature, the lower bound (Scenario 1) assumes no climate change; the mean annual temperature is projected to remain at the level of 2016 by 2050 and 2100. By contrast, Scenario 2 assumes a rise of the mean annual temperature (19° in Kigali) is projected to increase by 11.8% by 2050 (+2.2°) and by 29% (+5.5°) by 2100. For rainfall, the significant temperature increase in scenario 2 would likely lead to an increasingly polarized distribution of rainfalls in Scenario 2. As a result, the damage to crops from soil erosion, landslides and floods is likely to increase in Scenario 2. The climate projections used in this case study capture this effect through an annual yield loss (soil erosion) parameter.

To understand how the projected changes in temperature and rainfall would influence crop yields, the case study has developed **climate suitability functions** for both tea and coffee. The functions translate changes in the projected future climate to effects on tea and coffee production. The output for each crop is defined in two ways: yield (quantity) and quality (price). Both yield and quality are determined by a number of factors, including climate, soil type, nutrient and water availability, vegetative cover, cultivar, and management. The climate suitability functions developed in this case study attempt to isolate the impact of climate on the tea and coffees' yield and quality. They do so by defining a number of relationships: both for tea and for coffee, the yield and the price effects are expressed separately as a function of the temperature. For prices, the price of the product decreases as the temperature increases (since slower maturation at lower temperatures leads to higher quality and therefore higher price). By contrast, for yields, yield first increases as temperatures rise, until the optimal temperature is reached, after which yields decrease with increasing temperature. In addition, the effects of erosion (triggered by increased rainfall) on yields are also captured.

For both tea and coffee, **financial models** were then used to assess the yields and returns under different climate scenarios, and with or without adaptation measures. This was achieved in two steps. First, an input and output model for a one-hectare plantation captures the investment, operating and management costs, and the benefits in terms of average annual yield and price. This can be calibrated to specific plantations using price, productivity and climate data, and can be scaled up to represent the size in hectares of different project locations. Second, the plantation models were then tested in the different climate scenarios (first for a BAU case without adaptation measures in place). The impact of the climate scenarios on the crops' outputs (and inputs) is driven by the changes in yield and price associated with different climatic conditions, which are defined by the climate suitability functions (previous section). This is the private financial model for tea and coffee plantations without any intervention. In the financial model land is assumed to have an economic life of 50 years. Agricultural tools and materials are assumed to have an economic life of 1 to 10 years.

In terms of the adaptation measures and strategies analysed, the project followed two tracks: first, for existing plantations, it analysed a range of soil and water conservation measures for both tea and coffee plantations, as well as switching to a new coffee variety that is more resistant to drought and coffee leaf rust. Second, for new plantations, it investigated and compared the effect of climate risk maps to inform the geographical location of new plantations, using their altitude as a key parameter that determines the temperature, and hence the exposure to rising temperatures.

In the first track of analysis, the study investigated the (private) **costs and benefits of a range of soil and water conservation measures** as adaptation options. By changing the physical conditions in which tea and coffee are grown, these measures address current climate variability and the adaptation deficit in the tea and coffee sectors. The measures aim to provide private benefits to smallholders, in terms of improved yield and price that smallholders receive and the recovery of potential earnings lost from soil erosion. The options considered are hedgerows / grass strips, shade trees, tree belts, (Banana) intercropping and mulching.

The analysis then proceeded to calculate the net benefits of these adaptation options, relative to a baseline scenario without these measures, and for two different climate scenarios. The private costs of the measures (investment and maintenance costs for the farmer) are thereby calculated against the private benefits (mostly in the form of increased yields, but also other on-farm benefits). The results are presented as a range of net present values, calculated with a low (0%) and high discount rate (13%) for the two climate scenarios.

In addition to these soil and water conservation measures, which apply to existing coffee plantations, the analysis also considered newly established plantations with a drought and coffee leaf rust resistant variety of Arabica, called RABC15. The economic impacts of coffee leaf rust in terms of yield and quantity, and hence the benefits of avoiding it through a resistant variety, are difficult to quantify since there is a lack of evidence on the probability and severity of coffee leaf rust on a given plantation in any particular year. However, estimates from RAB indicate that coffee leaf rust may be responsible for an annual yield loss of 40% in Rwanda. This study therefore tests a range of direct coffee yield benefits for RABC15, from 0% to 40% higher than baseline yields associated with other varieties.

In the second track of analysis, the study employed a form of **portfolio analysis** to appraise the outcomes of an **investment into climate risk mapping**. Portfolio analysis is typically used to evaluate investments into different portfolios of options, in order to identify portfolios that yield the highest return for a given level of risk. In this case, the options considered are different altitude bands in which new tea plantations can be established (geographical choice). Portfolios are the different combinations of these options (altitude bands) that investors can choose to form their “plantation portfolio”. This study evaluates how the information gained from climate risk mapping could change the plantation portfolio chosen by the tea investors.

Average temperatures decline with altitude: for every 100 metres above sea level climbed, the temperature falls by 0.65° C. Combined with the varying tea yield and price at different temperatures, this means that tea plantations in one altitude band may perform differently to tea plantations in another. Without climate change, the relative performance of tea plantations in different altitude bands is likely to remain the same because the yield and price outcomes for tea in different altitude bands are constant. However, with climate change the yield and price of a tea plantation in a given altitude band is likely to change. The optimal altitude band for planting tea in a scenario without climate change may therefore be suboptimal in a future scenario with climate change.

This study uses annual mean temperature in different altitude bands to evaluate how tea plantations in these bands are expected to perform in different future climate scenarios. Altitude is divided into 10 x 100m bands from 1500 to 2500 metres above sea level. These bands are the individual options investors can choose to plant tea in to form their plantation portfolio. The temperature in these altitude bands is projected to remain the same in the low emissions scenario. However, in the high emissions scenario temperature is projected to increase by 11.8% by 2050 and 29% by 2100.

Without climate risk mapping, the investors can only use the Government of Rwanda's current tea expansion maps to decide where to plant tea. This is the business as usual (BAU) case where the optimal plantation portfolio is chosen under the assumption of no climate change. With climate risk mapping, the investors have additional information about the suitability of planting tea in different altitude bands under different future climate scenarios. This study first assesses the BAU plantation portfolio in climate scenarios 1 and 2, before considering how the climate risk mapping investment may change the investors' planting decision.

The financial cost of climate risk mapping is just under USD 150,000, of which 30% is tax and can be deducted for the economic analysis. The inputs are estimated to be 11% capital (data and software) and 89% skilled labour. Therefore, using the shadow price conversion factors the undiscounted economic cost of climate risk mapping is estimated to be just over USD 90,000, with 78% incurred in year 1, 4% in year 2 and 18% in year 3. Therefore, the investment into climate risk mapping will be economically worthwhile if it is able to inform the tea investors about plantation portfolios that generate returns greater than these USD 90,000, relative to the BAU plantation portfolio. This study assumes the difference in NPV between climate scenarios that is "acceptable" for the tea investors is the same as that in the BAU portfolio, i.e. USD 39.4 m at the 0% discount rate and USD 1.65m at the 13% discount rate. This represents the tea investors' uncertainty preference i.e. the acceptable difference in portfolio returns between climate scenarios.

Main implications and recommendations

The graph below shows the absolute economic return in each climate scenario. This approach allows the tea investors to see the difference in returns between climate scenarios, rather than aggregating information into one "expected value". The risk assessed in traditional portfolio analysis is represented by the difference in returns between the two climate scenarios, the outcome of which is fully uncertain. The analysis thus does not aggregate information into one "expected value", which would require assigning a probability weight to each climate scenario. Since there is no reliable data or local scenarios on which these weights could be based, the study refrains from making assumptions about the likelihood of either climate scenario, i.e. there is full uncertainty about the future climate.

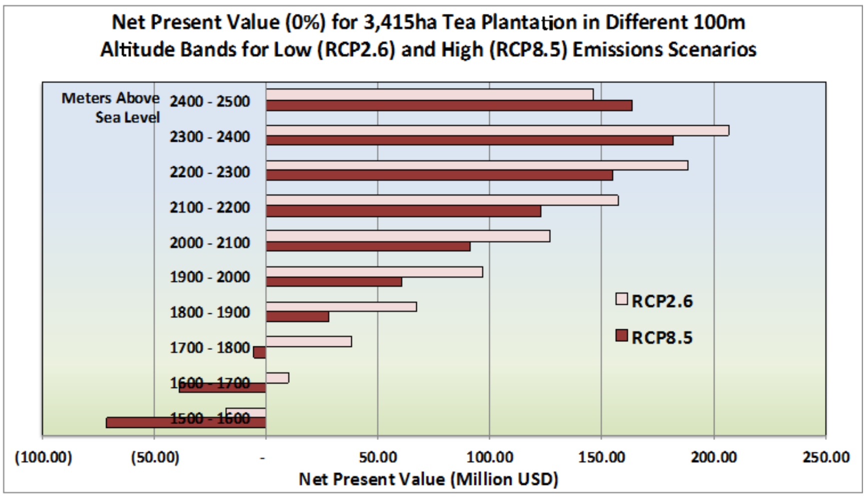

Figure 1: Net Present Value of tea plantation at different altitudes in Rwanda.

The graph shows that planting tea at an altitude between 2,300 and 2,400 metres above sea level is expected to produce the highest financial and undiscounted economic returns in both climate scenarios. However, at a 0% social discount rate, the absolute difference in returns between the two climate scenarios is lowest for plantations between 2,400 and 2,500 metres above sea level. This shows a trade-off between economic returns in each climate scenario and the absolute difference in economic returns between the two highest altitude bands; a higher difference in returns is rewarded with higher expected (absolute) returns.

In contrast, from 1,500 to 2,300 metres above sea level the returns increase in each climate scenario, whilst the absolute difference in returns falls. This means that tea investors can achieve higher returns for a lower absolute difference in returns between climate scenarios simply by planting tea at higher altitudes. In addition, the undiscounted economic results show that planting below 1,800 metres above sea level is expected to yield negative returns in the high emission scenario, and below 1,600 metres above sea level is expected to yield negative returns in both scenarios. With deep uncertainty between climate scenarios 1,800 metres above sea level is the lower economic threshold when a discount rate of 0% is used.

The returns to climate risk mapping depend on a number of uncertain factors, including the future climate, the plantation portfolio that is ultimately chosen by tea investors, and the indirect benefits and costs associated with disseminating and implementing the findings. This study shows positive returns to climate risk mapping across a wide range of these uncertainties; the worst-case scenario is no climate change and the tea investors choosing a plantation portfolio that is similar to the BAU portfolio. However, even this scenario has positive financial and economic returns (Internal rate of return of 47%, or USD 6.7 m at a 0% discount rate, and USD 0.6 m at 13%). In the “best-case scenario” with climate change, the returns to climate risk mapping are just over 20 times greater. Also, these figures do not cover any indirect benefits and costs. Given the scale of tea and coffee expansion in Rwanda, the magnitude of indirect “public good” benefits from climate risk mapping will probably outweigh the costs of disseminating and implementing the findings. As a result, the investment into climate risk mapping is estimated to generate even greater positive financial and economic returns when accounting for the wider indirect benefits and costs.

Bibliography

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Further Information
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