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The Economics of Adaptation

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Developing Country Economic Appraisal Case Studies.

Lessons learned, policy recommendations, and guidance.

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Executive Summary

The objectives of this work package are to:

- Undertake a case study on the economics of adaptation in the context of international development support.
- Undertake this work on a real case study example aligned to developing country adaptation flows and analysis.
- Consider lessons learned and transferability of the case study to methods and guidance.

Consistent with international pledges, there will be very large increases in European overseas development assistance to developing countries, and a likely greater need to demonstrate that these financial resources are being used effectively. This assistance will be dispersed through bi-lateral and multi-lateral arrangements, and range from support for national processes through to individual projects.

This work package investigates the economics of adaptation in relation to these flows and policy contexts. The analysis is undertaken in collaboration with developing country partners in real applications looking at project and programme level adaptation implementation. Four case studies within two country studies are selected: Rwanda tea and coffee production, and; Zanzibar seaweed and clove production. They selected in conjunction with the principal stakeholders: primarily government ministries, producers and exporters. This process ensured that the research is more likely to be incorporated in respective sectoral development plans. It also provided a means with which to ensure that adaptation options were developed in the wider policy context that investment decisions are made.

Principal conclusions include:

First, consistent with current practice in development economics, the analyses illustrate the continued importance of estimating shadow prices – market and non-market – for a range of parameters included in the economic analyses. The main market parameters for which shadow prices include the wage rate, distributional weighting, and the discount rate. All constitute a significant form of uncertainty in the analyses, additional to climate change scenarios. Non-market shadow prices include carbon prices and ecosystem damages.

By way of highlighting this point, the seaweed analysis demonstrates the importance of non-market values in climate adaptation interventions. Across all scenarios, appraisals including non-market costs and benefits present much higher returns than financial cash flows alone. This indicates that the adaptation options generate significant social value. Economic, environmental and social benefits of all interventions provide ample opportunity for productive public investment in the sector. Similarly, while global damage assessments have long recognised inequities in climate impacts across regions in the world and between national income groups, they have been less prominent in local analyses. The seaweed case study highlighted gender impacts as an important distributional dimension in the assessment. With distributional weights included in economic valuation, the appraisal demonstrates how a political consideration can be included quantitatively alongside other costs and benefits.

Second, the case studies serve to illustrate that economic decision-support methods that have been developed to better incorporate non-probabilistic uncertainties, of the type presented by climate change projections, can be applied in developing country contexts. In each of the three case studies, these methods – Portfolio Analysis in Rwanda, Real Options Analysis in Zanzibar – are shown to add a further, additional, level of insight to the information that conventional methods such as Cost-Benefit Analysis can convey.

However, third, and as a caveat to the second conclusion, the resource requirements associated with undertaking these more sophisticated methods remain considerable. In the case of the Portfolio Analysis of tea-planting strategies, the data processing was very time-consuming and required a relatively high level of numeracy. The applications of Real Options Analysis – whilst simplified into a decision-tree approach – also required a relatively high degree of knowledge of these methods. It seems, therefore, that the holy grail of "light touch" methods is not quite yet in sight. Certainly, future research needs to focus on simplified approaches to the treatment of uncertainty in adaptation appraisal, as well as effective communication of the results of these appraisals.

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1 Introduction

The objectives of WP9 - Case study: International Development Support - are to:

- Undertake a case study on the economics of adaptation in the context of international development support.
- Undertake this work on a real case study example aligned to developing country adaptation flows and analysis.
- Consider lessons learned and transferability of the case study to methods and guidance.

Consistent with international pledges, there will be very large increases in European overseas development assistance from Europe to developing countries for adaptation. This assistance will be dispersed through bi-lateral and multi-lateral arrangements, and range from support for national processes through to individual projects. However, there is also a growing focus at EU and Member State level to demonstrate that this financial resource is being used effectively.

At the same time, the empirical issues identified in the case studies in WPs 5-7 of ECONADAPT are also directly relevant for international development assistance for adaptation, but face additional challenges. First, there is a much greater focus on addressing existing climate variability (the adaptation deficit) in developing countries (see Parry et al, 2009) leading to a focus on no-regret options (Ranger et al, 2011). Second, it is acknowledged that a response to a given climate risk needs to be placed within the context of development objectives (see e.g. Fankhauser (1997) and Callaway, (2003). However, to date, the mapping of these often competing objectives is rarely explicit in either appraisal guidance or in practical decision-making; the best-known attempt at this mapping has been undertaken by Hellmuth and Callaway, (2006). This also leads to the question of the degree of additionality over development funding resulting from the incorporation of climate change risks. The strong overlap between early adaptation and development is particularly important in this context given the way in which the UNFCCC Adaptation Fund structures development support on the basis of this additionality (Klein and Persson, 2008; McGray et al, 2007). Finally, the complexity of the developing country context is exacerbated since there are much found to be much greater challenges in terms of data availability, governance and institutional capacity in developing countries.

In the case studies within WP9 we have considered the transfer of the techniques developed elsewhere in the project to the developing country context in the light of international development flows. On the basis of consultation with the EC DG DEVCO, UK DFID and other donors, we focussed our research on case studies undertaken in Rwanda and Tanzania as the locations to help ground the case studies in a real context.

Based on the discussion above, suitable case studies were sought in Least Developed Countries, with a focus on two case studies reflecting national adaptation planning and climate mainstreaming. The first case study is undertaken in Rwanda, a highly climate vulnerable post-conflict country in Africa. This works with a European international development assistance organisations (UK DFID) and its support for the Government of Rwanda, particularly in the mainstreaming of adaptation into the National Agriculture Sector Investment Plan and the linkages to the Rwandan national climate fund (FONERWA). Discussions were held with DFID, the FONERWA team and the Rwandan Ministry of Agriculture (MINIAGRI) during the reporting period to agree the case study. The case study provides an example of mainstreaming adaptation into sector development planning, focusing on the economic analysis.

The second case study is in Zanzibar, in the United Republic of Tanzania, a small, developing-island, which has areas of high vulnerability to climate change. We worked directly with the Revolutionary Government of Zanzibar, helping to develop its Climate Change Action Plan (equivalent to a National Adaptation Plan), working on the economic prioritisation of options and the costing of these for potential international financing. The aim of the case study was to provide a prioritised and costed action plan. Discussions were held with the Government in autumn 2014 to agree the case study.

The following sections summarise the case studies before providing a synthesis of lessons learnt from these studies.

2 Rwanda Case Study: Tea and Coffee cropping

2.1 Policy and research questions

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 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. 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.

The key research question is therefore: to what extent is it possible to apply economic decision support tools in the context of tea and coffee farming investments in Rwanda?

2.2 Analysis and key findings

Analysis

In the first wave of analysis, the study investigated the (private) costs and benefits of a range of soil and water conservation measures as adaptation options in coffee plant growing. 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 wave 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.

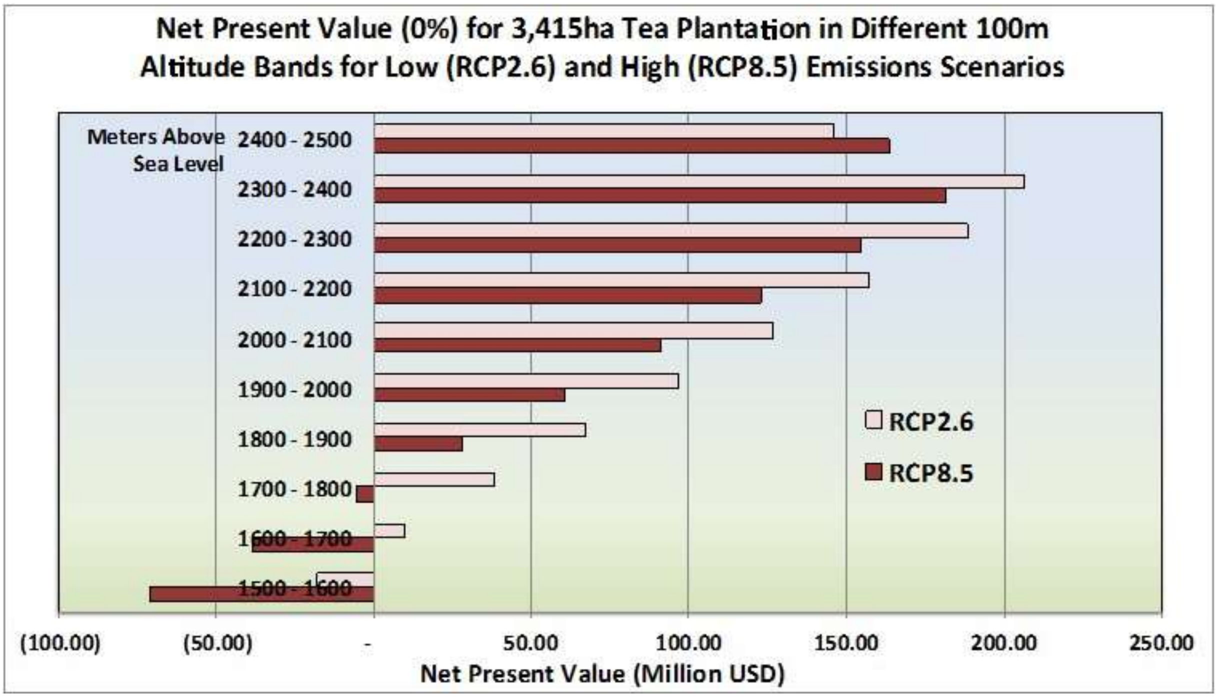
This study uses annual mean temperature in different altitude bands to evaluate how tea plantations in these bands are expected to perform in different future climate scenarios. Altitude is divided into 10 x 100m bands from 1500 to 2500 metres above sea level. These bands are the individual options investors 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

Findings

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. Our 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.



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.

3 Prioritisation of adaptation in the development context: Zanzibar – Seaweed Farming

3.1 Policy and research questions

This case study evaluates different options to adapt seaweed farming in the Zanzibar islands to the impact of a changing climate. Seaweed is a main export product of the Zanzibar economy, and seaweed farming a major source of employment in rural coastal communities, particularly for women. In fact, seaweed farming represents one of the only income sources for women in coastal villages. A recent government census estimates over 20,000 farmers currently active in Zanzibar.

As an economic activity, seaweed farming is particularly vulnerable to the impacts from climate change – some of which have already begun to affect the industry. A main threat is from higher sea surface temperatures, which have been identified as a cause of the so-called ice-ice disease, killing seaweed plants before they can be harvested. Past increases in sea surface temperatures have already been associated with a significant reduction in the farming of *cottonii* seaweed: while this variety is economically more attractive (due to its higher carrageenan content, it attracts higher prices on the world market), farmers have been unable to harvest healthy *cottonii* seaweed due to an increase in disease thought to be linked to rising sea surface temperatures. Therefore, farmers have resorted to a different variety – *spinosum*, which has a lower carrageenan content and therefore commands a lower price, but is more resilient to higher sea surface temperatures. However, above a level of 40°C seaweed farming may become infeasible, which would lead to an elimination of the industry. The loss of *cottonii* as a viable off-bottom crop and the potential future loss of *spinosum* in warmer waters pose an essential economic threat to the region, in which many coastal villagers depend on the seaweed industry for their income and livelihood.

In addition to the threat from higher sea surface temperatures, there is also the threat of more frequent extreme weather events and changes in weather patterns: strong winds and waves are estimated to break off up to 50% of a seaweed crop in stormy seasons, while longer rainy seasons prevent drying of seaweed, requiring farmers to forego a full 45-day cycle of seaweed growth.

The distribution of benefits across the population is a particular concern amongst officials in Zanzibar. Seaweed farming has been celebrated as an important industry for women in Zanzibar, as women in rural coastal villages have no other revenue-generating activity to rely upon for additional resources, while men—especially on Unguja—have opportunities to find employment in construction, harvesting and other labour-intensive sectors around the island. Income from seaweed farming is used to purchase clothing, food and make house improvements (Msuya, 2013). Off-bottom farming methods included in the baseline scenario allow for broad participation from women. Across Zanzibar, 57% of seaweed farmers are women. On Unguja island, 93% of all seaweed farmers are women.[2]

The practice of floating line farms risks reducing the benefits women gain from the sector, as the seaweed is grown in deeper waters than are currently used. Women are rarely taught how to swim in the communities currently involved in seaweed farming. To preserve gender benefits in a switch from off-bottom to floating line farming methods, precautions must be taken to enable women to participate without having to enter deep waters. The use of family-sized boats in floating-line seaweed farms can preserve female participation by allowing women to remain on boats to tie seedlings and assemble floating line frames while male farmers install anchors and carry out in-water maintenance. With complete compliance, the family boat model would reduce female participation to 50% of the farmer workforce. Family-sized boats are included in the cost-benefit analyses carried out in this appraisal, but must be implemented with proper education and awareness-raising measures in order to preserve gender benefits from seaweed farming.

The key research questions are therefore: how can we account for climate risk uncertainty in project appraisal in the seaweed production process, and: how can distributional effects be incorporated in such appraisal?

3.2 Analysis and key findings

Analysis

The case study investigated different ways in which seaweed farmers could respond to the threat of rising sea surface temperatures, and assessed the costs and benefits of the different options. The investigated options included a variety of deep-water floating raft farm methods to replace the current off-bottom shallow water method. In this way, seaweed crops are moved to deeper waters where temperatures are lower and more stable and sediment is less present at the level of the seaweed plants. In addition, a programme to gather information on temperature changes around the islands was investigated as an additional measure. The information from this programme would then be used to inform long-term strategic decisions. In appraising the floating raft farm options, 35-year cost benefit analyses were calculated under a number of discount rates, including official European and international rates as well as higher commercial lending rates.

A fundamental challenge for the case study was dealing with uncertainty – both related to climate change scenarios and their impacts, and to an uncertain economic outlook. Longer term uncertainty in the seaweed farming sector stems from ambiguous climate futures past 2040. Climate projections past this point suggest temperature increases of varying magnitudes, depending on the emissions pathway assumed. The low emissions scenario projects temperature increases that remain in a viable range for growing at least one species of seaweed in Zanzibar. However, under a higher emissions scenario temperatures would exceed the threshold for both *spinosum* and *cottonii* seaweed varieties by 2075. In the case of a high-emissions future, returns from investments in seaweed farming may fall to zero if sea temperatures exceed the threshold for all varieties. In this scenario, medium- and long-term pursuit of adaptation options investigated in the cost-benefit analysis may not provide a positive economic return – instead, diversification and exit strategies would be needed for those communities reliant on seaweed farming. Since the uncertainty around climate sensitivity cannot be resolved, policymakers cannot reliably project the viability of seaweed farming past mid-century. Beyond this point, rather than comparing the short-term costs and benefits of different options, it is more appropriate to plan for alternative outcomes using flexible decision-making tools such as Real Options Analysis or decision trees.

The uncertainty of climate change impacts and their effect on seaweed farming is compounded by the economic uncertainty of how seaweed prices will evolve. Global seaweed prices differ across species of seaweed, depending on the export market for each type of seaweed. While demand for *cottonii* remains high, very few farmers in Zanzibar are able to produce any of this species without losing the entire harvest to disease. Instead, *spinosum* is primarily grown and faces a much more volatile market. Current prices for *spinosum* are amongst the lowest in five years, causing some farmers to exit the industry. But as many do not have alternative income sources, they continue to grow seaweed at minimal profit.

In comparison to the baseline, the case study investigated the following adaptation options:

- **Adaptation Option 1. Farm *spinosum* off of deep-water floating rafts.** This adaptation option assumes that farmers abandon current off-bottom farming practices in favour of growing seaweed on floating rafts in 2-3 meters of seawater. This method has been shown to be more productive in seaweed harvested, as compared to off-bottom growing methods.

- **Adaptation Option 1.1. Farm *cottonii* off of deep-water floating rafts.** This option assumes the same switch from off-bottom to deep-water floating rafts as the previous option, but substitutes the more valuable *cottonii* species for *spinosum*. Because of lower sea surface temperatures in deeper waters, floating-line farms are able to support *cottonii*, even in areas where it is not possible to grow the species using the off-bottom farm method.

- **Adaptation Option 1.2. Farm *cottonii* off of deep-water floating rafts with net enhancement.** This option is responsive to the observed loss of up to 50% of seaweed grown on floating rafts during storm periods, in which heavy winds, rains and waves destroy the crop growing on raft farms. An enhanced raft design using PVC pipes and fishing nets has been tested and shown to reduce storm loss to 10% of normal crop levels.

- **Adaptation Option 1.3. Farm *cottonii* off of deep-water floating rafts with greenhouse drying facility enhancement.** This option responds to losses in seaweed harvest during rainy seasons. Farmers report leaving seaweed on lines in the water when rains come during stormy seasons, as the standard drying process requires sunshine to dry harvested seaweed on beaches. Observed losses to date amount to an entire farm cycle, or one-eighth of annual income. The use of sheltered greenhouses to dry seaweed would allow for harvest during rainy seasons and reduce contamination in farmed product.

- **Adaptation Option 2. Invest in climate information infrastructure to inform future decision points.** Separate from farming method options, this investment presents the costs of gathering data on sea surface temperature around the Unguja and Pemba islands. Short-term investments in information include the installation and maintenance of sea surface temperature loggers around Pemba and Unguja. The additional value that local temperature loggers can provide is in understanding whether and how different areas around Zanzibar respond to climate change. If temperature increases appear to be following a high-emissions scenario, it may be more beneficial in the long term to consider exit and diversification strategies for seaweed farmers in certain areas.

The different options were then assessed in an extended cost-benefit analysis, which included both financial and economic analyses. The financial analysis compares the costs of the different options to the private market benefits, i.e. increased seaweed yields. The economic analysis also includes non-market costs and benefits. Non-market values for the baseline scenario include 1) economic benefits from the additional revenue generated by export sales after farm-gate prices are accounted for and 2) distributional benefits from the creation of income for rural women. In addition, the different adaptation options also give rise to different non-market benefits. These included avoided health costs associated with off-bottom farming, avoided disruptions of marine ecosystems stemming from frequent movement across shallow sea-beds, avoided impacts on coastal mangrove forests (otherwise used for foraging for wood to use as stakes for seaweed lines), avoided impacts of seagrass destruction (as a side-effect of off-bottom farming), as well as the value of fish bycatch that is attracted to the floating raft farms.

To compare the results, the net cash flow was calculated over a 35-year period for the baseline scenario and each adaptation option using a low (3.5%), intermediate (10%) and high (16%) discount rate. Finally, financial and economic Internal Rates of Return (IRR) are generated for the baseline scenario and each adaptation option. This number represents the return on resources invested into the project (costs), presented as a comparison to returns on the same resources if they were invested elsewhere. Benefit-cost ratios for each option are also calculated to represent economic and financial returns on investment.

In order to capture the benefits of providing an income stream to women in particular, the project appraisals apply distributional weights as discussed in ECONADAPT Deliverable 2.3 (Rouillard et al, 2016). In order to illustrate the value of benefits accrued by a group with no access to regular income—women in coastal villages—distributional weights are calculated by comparing average rural male income in Zanzibar to average female income in Zanzibar:

$$Distributional\ Weight = \frac{Average\ rural\ male\ income}{Average\ rural\ female\ income}$$

Using 2009/2010 data, the ratio of male to female income in rural areas is 3.02, representing a preference for female income due to disparate wages between genders in rural areas (RGZ, 2012). Total benefits are calculated in the economic valuation of the appraisal by substituting weighted income equal to the proportion of farm workforce that women comprise (I.E. in the baseline scenario, 57% of seaweed income would be multiplied by the distributional weight).

In addition to demographic distributional concerns, geographic disparities between Unguja and Pemba should be considered where present. At present, 70-80% of all seaweed farming in Zanzibar is carried out on Pemba island. Little information is available as to differences in climate risks faced by each of the two islands. Investments in climate monitoring technology for both Pemba and Unguja islands could help policymakers track where risk to seaweed farming is greatest and respond appropriately. As the islands have different geographical features, they may experience climate change at different rates and a tailored adaptation plan may be appropriate for each island. Assessing the distribution of climate impacts across the two islands will only be possible with improved climate information.

Findings

The study found positive returns, both in the form of financial returns and in terms of the social welfare generated from all adaptation options included in the analysis. That said, the baseline scenario itself (continuing to farm *spinosum* seaweed using the off-bottom method) showed a strong and positive dynamic, with positive net present values and a high internal rate of return. The baseline IRR is already 353% if only the financial costs and benefits are considered, and 1036% if all economic costs and benefits (including non-market values) are included. This is echoed in a favourable benefit-cost-ratio of 5.1:1 for financial costs, and more than 14:1 for economic costs. Compared to this, the financial return of the different adaptation options is either almost as large (Options 1.1, 1.2) or significantly lower than the baseline – but still highly positive (Options 1, 1.3). This is somewhat different when the scope of the analysis is extended and economic costs and benefits are included: in this case, the internal rate of return is of a similar magnitude for all options, with two options (1.1, 1.2) generating slightly a higher return than the baseline, and two others (1, 1.3) slightly lower.

Distributional effects of seaweed farming as well as discount rates applied in analysis both have important implications for interpreting the findings of this analysis. Distributional impacts of any intervention are of high interest to policymakers as seaweed farming represents a unique source of income for women in coastal villages. With no alternative, adverse impacts on women farmers should be avoided wherever possible. Introducing floating raft farms may bring a reduction in female farmer participation as a proportion of all farmers, shifting from the *status quo* female farmer share of 57% to 50%. In Unguja, this switch would be more pronounced; currently over 90% of seaweed farmers in Unguja are female. Though the share of female farmers drops in the adaptation options, non-market values of distribution-weighted income to females increases in all of the adaptation options over the baseline scenario, due to higher total incomes. Over the long-term, the seaweed farming growth strategy could target equal growth across genders in order to preserve maximum distributional benefits from the sector.

4 Adaptation decision-making in Zanzibar's clove plantations

4.1 Policy and research questions

In this study we aim at testing methodologies that can handle climate change uncertainty and their pertinence to adaptation in international development cooperation by adopting "light touch" approaches that capture intrinsic concepts of formal applications without losing their economic rationale. To do so, we use the ongoing National Adaptation Action Plan process of the Revolutionary Government of Zanzibar within the United Republic of Tanzania (URT) where stakeholders identified clove plantations as one of the key priorities to be addressed. From the perspective of project finance application we first develop a cost benefit analysis of a simplified clove agroforestry systems focusing on Pemba Island. We assess the profitability of different adaptation options that aim at resilient clove plantations in Zanzibar both with and without climate change. We then extend the analysis to Real Option Analysis (ROA) and Robust Decision-Making (RDM), light touch uncertainty treatments to verify their relevance for the adaptation practitioner community in the field.

4.2 Analysis and key findings

Analysis

In this study we analyse the profitability of different adaptation options in clove plantations of Zanzibar under both current and projected climates for the future. In a first step, we develop a CBA on a simplified agroforestry model including a baseline and four alternative agricultural practices and analyse their viability under present climate. Subsequently, we analyse results from introducing future climate impacts in the form of rainfall projections and extreme events in form of a cyclone hitting at three different timings. We then look into economic outcomes resulting under current, future climate and cyclone events. In a second step, we look into conceptual aspects of real option analysis (ROA) that we apply in a light touch treatment to our agroforestry model. Finally, we compare results from the CBA and ROA and conclude about the relevance of these methodologies to development project applications.

To illustrate possible applications of the ROA methodology, we develop a decision tree together with potentially "in-project" flexible adaptation options to compare results with the traditional cost benefit analysis. We look especially into good management practices which the cost benefit analysis suggest are profitable even under no climate change. We also look more closely at the windbreak which is according to the cost benefit analysis, the less profitable option under no climate change impact but profitable under cyclone impact. In our decision tree we suggest two sources of uncertainty: (i) the clove price (low/high) and (ii) the prevailing climate change regime (no Climate change/RCP4.5 or 8.5). To simplify the analysis we here consider a unique discount rate of 10%.

We test adaptation investments that might create flexibility during the timeline of our investment. The idea is that investing an amount somewhere half way between nothing and 100% of good management practices would avoid either to overinvest or to underinvest. For this purpose we divide our timeline of 80 years into two distinct periods: period 1 stretching from 2016 to 2049 and period 2 from 2050 to the end of the century. This way, we are able to propose gradual stage decision making instead of a now or never investment. We propose an investment of 50% of initial GMPs in the first period with two possibilities in the second one: either continue investing the remaining 50% or renounce to that investment.

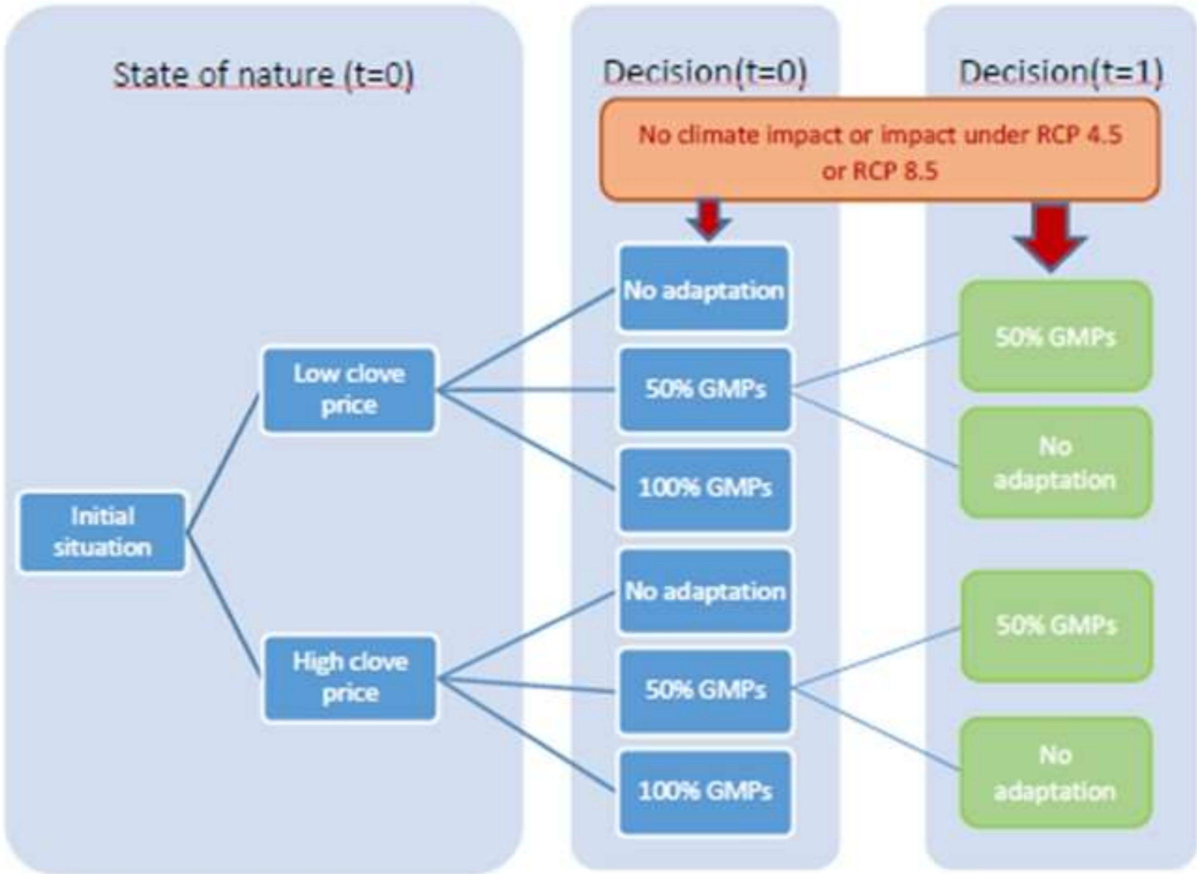


Figure 1: Decision tree for good management practices (GMPs). To keep the decision tree understandable, prices are assumed to remain on their initial path of t=0 in the next period 1.

NPVs per period both for high and low prices are calculated. A matrix is then constructed with NPVs of both periods for low and high prices to which we add four types of probabilities: probabilities of low or high prices, probabilities of no climate impact and probabilities of RCP 4.5 and RCP 8.5. We then calculate expected NPVs for high and low prices separately before considering the total expected value given uncertainties about high and low prices altogether.

In the first step of our analysis we assume a 40% probability for clove prices being low and 60% for the high price case. In addition, the probabilities of no climate change occurring is assumed to be 45% for illustrative purposes. RCP 4.5 and RCP 8.5 probabilities of occurrence are set at 25% and 30% respectively.

In a second step we conduct a sensitivity analysis: In a first case, we vary RCP probabilities while keeping price and no climate change probabilities fixed[1]. In a second case, we look into 50% probability of either high or low prices and no changes in climate probabilities. In a third case, we analyse the situation when only the probability of no climate impact varies. To keep the analysis comprehensive, all sensitivity analysis are done separately.

Findings

The ROA indicates that investment in clove plantations and good management practices is not profitable under low prices. If the farmer knew the price would remain low forever she would neither invest in clove plantations as a whole nor in good management practices. However, in reality, a farmer might be tempted to invest today even if the price is low because she would expect an increase in the future that might be worth waiting for. This is reflected in the expected NPV when both price probabilities are taken into account, with a 60% probability of high prices.

Interestingly, a second result shows that, although not an optimal strategy because it does not earn maximum profit, when investing 50% in the first period it is better to continue investing in the second period than stopping the investment in period two. This is so both in the case under low and high prices. Although the CBA gives an intuition about the profitability, ROA provides more information by suggesting how decisions and outcomes might look like after an investment is realised.

[1] In this case while both RCP probabilities summing up to 55%, one is decreased while the other is increased.

5 Conclusions

The three case studies across the two developing countries – Rwanda and Zanzibar – are designed to have practical use in determining future adaptation investments. Thus, the four products – coffee, tea (Rwanda); seaweed, cloves (Zanzibar) – were selected in conjunction with the principal stakeholders: primarily government ministries, producers and exporters. This process – reported in detail in D9.1 – ensured that the research is more likely to be incorporated in respective sectoral development plans. It also provided a means with which to ensure that adaptation options were developed in the wider policy context that investment decisions are made. An indicator of the effectiveness of this approach is the fact that evolved versions of the coffee and tea analysis undertaken in Rwanda are now being used as the basis for part of an application by the Rwandan Government to the Green Climate Fund established by the UN.

Other principal conclusions are outlined in the following paragraphs.

First, consistent with current practice in development economics, the analyses illustrate the continued importance of estimating shadow prices – market and non-market – for a range of parameters included in the economic analyses. The main market parameters for which shadow prices include the wage rate, distributional weighting, and the discount rate. All constitute a significant form of uncertainty in the analyses, additional to climate change scenarios. Non-market shadow prices include carbon prices and ecosystem damages.

By way of highlighting this point, the seaweed analysis demonstrates the importance of non-market values in climate adaptation interventions. Across all scenarios, appraisals including non-market costs and benefits present much higher returns than financial cash flows alone. This indicates that the adaptation options generate significant social value. Economic, environmental and social benefits of all interventions provide ample opportunity for productive public investment in the sector. Similarly, while global damage assessments have long recognised inequities in climate impacts across regions in the world and between national income groups, they have been less prominent in local analyses. The seaweed case study highlighted gender impacts as an important distributional dimension in the assessment. With distributional weights included in economic valuation, the appraisal demonstrates how a political consideration can be included quantitatively alongside other costs and benefits.

Second, the case studies serve to illustrate that economic decision-support methods that have been developed to better incorporate non-probabilistic uncertainties, of the type presented by climate change projections, can be applied in developing country contexts. In each of the three case studies, these methods – Portfolio Analysis in Rwanda, Real Options Analysis in Zanzibar – are shown to add a further, additional, level of insight to the information that conventional methods such as Cost-Benefit Analysis can convey.

However, third, and as a caveat to the second conclusion, the resource requirements associated with undertaking these more sophisticated methods remain considerable. In the case of the Portfolio Analysis of tea-planting strategies, the data processing was very time-consuming and required a relatively high level of numeracy. The applications of Real Options Analysis – whilst simplified into a decision-tree approach – also required a relatively high degree of knowledge of these methods. It seems, therefore, that the holy grail of “light touch” methods is not quite yet in sight. Certainly, future research needs to focus on simplified approaches to the treatment of uncertainty in adaptation appraisal, as well as effective communication of the results of these appraisals.

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