Ecological Economics 151 (2018) 142–150

Contents lists available at ScienceDirect

Ecological Economics

journal homepage: www.elsevier.com/locate/ecolecon

Analysis

Evaluation of Climate Change Adaptation Alternatives for Smallholder Farmers in the Upper Blue-Nile Basin

Yalemzewd Nigussie[a,b], Edwin van der Werf[a,c,*], Xueqin Zhu[a], Belay Simane[b], Ekko C. van Ierland[a]

[a] Environmental Economics and Natural Resources Group, Wageningen University & Research, The Netherlands
[b] College of Development Studies, Addis Ababa University, Ethiopia
[c] CESifo, Munich, Germany

ARTICLE INFO

Keywords:
Adaptation
Agriculture
Stakeholders
Climate change
Multi-criteria analysis
Ethiopia

ABSTRACT

Climate change is expected to have severe negative impacts on the livelihoods of smallholder farmers in developing countries. However, smallholder farmers and governments in these regions tend to be ill-prepared for the impacts of climate change. We present the results of a stakeholder-based multi-criteria analysis of climate change adaptation options for agriculture, natural resource management and water management in the upper Blue-Nile basin in Ethiopia. We use the PROMETHEE II outranking method to analyse data from a survey in which farmers and experts were asked to evaluate adaptation options based on potentially conflicting criteria. Adaptation options for soil and land management, such as crop rotation and composting, score high based on two sets of criteria for assessing adaptation options for agriculture. River diversion, preventing leaching and erosion, and drip irrigation are ranked highest as adaptation options for water management. Regarding natural resource management, the highest ranked adaptation options are afforestation, water retention and maximizing crop yield. Rankings by farmers and by experts are weakly correlated for agriculture and water management, and negatively correlated for natural resource management, which shows the importance of extension services and of involving farmers in the decision-making process to ensure the feasibility of adaptation options.

1. Introduction

Since the risks associated with climate change are real but uncertain, societies need to develop adaptation strategies, especially for those who are highly vulnerable (Adger et al., 2003). The consequences of climate change for developing countries are more severe than for developed countries due to low adaptive capacity and high vulnerability in developing countries. For example, Ethiopia is heavily dependent on rain-fed agriculture, and its geographical location and topography in combination with low adaptive capacity imply a high vulnerability to adverse impacts of climate change. Historically, land degradation in the form of soil erosion has negatively affected agricultural production and economic development in Ethiopia (Balana et al., 2010). Rainfall variability and recurrent droughts result in a fluctuating run-off to the Nile tributaries (World Bank, 2010, 2015).

Several studies have proposed strategies, both at the micro and the macro level, to tackle problems related to the effects of climate change and natural resource degradation in Ethiopia (e.g. Deressa et al., 2008; Di Falco et al., 2011; Tesso et al., 2012; Tesfaye and Brouwer, 2012; Simane et al., 2012, 2013). Since policy interventions for climate change adaptation require participation of and dialogue with stakeholders, stakeholder analysis has become a tool for prioritizing adaptation options in various countries (e.g. Champalle et al., 2015; Dilling and Berggren, 2014). Since long-term impacts of climate change in Ethiopia are expected to be severe (Conway and Schipper, 2011; World Bank, 2010), adaptation options identified through empirical research and government policies and programs need to be evaluated and prioritized by stakeholders from different groups. However, there is a lack of stakeholder-level evaluation and stakeholder dialogue to identify adaptation options on the basis of well-defined evaluation criteria in the process of adaptation to climate change at different hotspots, such as the upper Blue-Nile basin in Ethiopia.[1] Previous studies about adaptation in the upper Blue-Nile basin have failed to evaluate adaptation options based on (possibly conflicting) criteria. Due to a lack of resources and skills, adaptation interventions in Ethiopia are designed without considering the specific characteristics of the agro-ecosystem

* Corresponding author at: Environmental Economics and Natural Resources Group, Wageningen University & Research, P.O. Box 8130, 6700EW Wageningen, The Netherlands.
E-mail address: edwin.vanderwerf@wur.nl (E. van der Werf).

[1] An exception is the Ethiopian National Adaptation Plan of Action (NAPA, 2007), which is a stakeholder level project evaluation framework developed on the basis of cost benefit analysis.

https://doi.org/10.1016/j.ecolecon.2018.05.006
Received 15 November 2016; Received in revised form 30 November 2017; Accepted 8 May 2018
0921-8009/

(Simane et al., 2012). This gap can be filled through an approach that enables stakeholders' engagement in the different stages of the assessment of relevant adaptation options.

In this paper, we rank and evaluate possible adaptation options for smallholder farmers in the upper Blue-Nile basin using a set of conflicting criteria, using information from both local farmers and experts. We used a stakeholder workshop and a survey of farmers and experts to identify alternative adaptation options, select evaluation criteria and collect data. We subsequently analysed these data using the PROMETHEE II preference outranking method for Multi-Criteria Analysis (MCA). MCA is a decision-support tool applicable to choice problems in different contexts under a number of different alternatives and possibly conflicting criteria (Hajkowicz et al., 2000). It is an evaluation method used to rank or score the performance of alternative (policy) options against multiple criteria (Hajkowicz, 2007).

We find that adaptation options for soil and land management – such as crop rotation, composting and changes of fertilizer use methods – score high based on two sets of criteria for assessing adaptation options for agriculture. River diversion, preventing leaching and erosion, and drip irrigation are ranked highest as adaptation options for water management. Regarding adaptation options for natural resource management, the highest ranked options are afforestation, maximizing water retention and maximizing crop yield. When analysing the data from experts separately, we find that the ranking by farmers and the ranking by experts are only weakly correlated for agriculture and water management, and even negatively correlated for natural resource management. This shows the importance of extension services and of involving farmers in the decision-making process to ensure the applicability and socio-economic feasibility of the chosen adaptation options.

The paper is organized as follows. Section 2 presents the materials and methods including the identifcation and evaluation process of adaptation options by MCA. Section 3 presents the rankings based on uni-criterion analysis and MCA. We provide concluding remarks in Section 4.

2. Materials and Methods

2.1. Multi-criteria Analysis

There are different methods to assess and prioritize alternative policy options for climate change adaptation (Zhu et al., 2016). In Cost Benefit Analysis (CBA), the benefits and costs of adaptation are expressed in monetary terms, and the net benefits are calculated. Applicability of CBA is limited for many adaptation options since benefits of climate change adaptation do not always have a clear monetary value (see e.g. Palma et al., 2007; De Bruin et al., 2009). Similarly, Cost Effectiveness Analysis (CEA) also requires monetization of costs which is not always feasible in the context of the study. In addition, the costs of an adaptation option may differ between farmers. Because of these drawbacks of CBA and CEA we have chosen Multi-Criteria Analysis (MCA) as method to rank the adaptation options that combines qualitative and quantitative approaches (e.g. Palma et al., 2007; De Bruin et al., 2009; Pearce et al., 2012; Hayashi et al., 2014). MCA is a systematic method for assessing and scoring options against a range of decision criteria. In contrast to other qualitative and participatory approaches (e.g., Analytic Hierarchy Process), the main strength is that MCA provides a systematic method for assessing and scoring options, some of which are expressed in physical or monetary units, and some which are qualitative. The various criteria can then be weighted to provide an overall ranking of options. These steps are undertaken using stakeholder consultation and/or expert input. MCA has been widely applied in the environmental domain and has also been used as a tool for adaption analysis (e.g. De Bruin et al., 2009).

There are three approaches to MCA. The first is rooted in multi-attribute utility theory, which requires the identification of utility functions and weights for each attribute that can then be assembled in a unique synthesizing criterion (Keeney and Raiffa, 1993). The second approach in MCA refers to interactive methods. These require preference information from the decision-maker throughout the selection process and require progressive articulation of preferences (see for example Geoffrion et al., 1972). The third MCA approach is the outranking method. It focuses on building a relation called "outranking relation", which represents the decision-maker's preferences. Ranking of the alternatives is done on the basis of pair-wise comparisons of alternatives (choices). Examples of well-known outranking methods are PROMETHEE (Brans and Vincke, 1985), ELECTRE (Roy, 1973), and MACBETH (Bana e Costa and Vansnick, 1997). Cinelli et al. (2014) provide an overview of MCA methods for sustainability assessment.

In this paper, we use MCA to evaluate adaptation options. In the implementation of MCA, we need to make pair-wise comparisons of alternatives to establish the ranking of the alternatives. Particularly for ranking the alternatives, we choose the Preference Ranking Organization Method for Enrichment of Evaluations (PROMETHEE), which can make pair-wise comparisons of all alternatives and therefore allows for the ranking of alternatives based on a set of evaluation criteria, where each criterion has an assigned weight (Brans and Vincke, 1985). PROMETHEE methods are widely used in the evaluation and ranking of environmental options (e.g., Palma et al., 2007; Jactel et al., 2012). PROMETHEE is transparent, and enables the absolute ranking of the options and showing the relative position of the various options that are considered. It also allows for sensitivity analysis of the weights used, and for establishing a weight stability interval (see Section 3.2.2 below). PROMETHEE has advantages over other methods (e.g. ELECTRE and MACBETH) in terms of data management and specifically its representation, supporting comparisons of scenarios, visualization of the influence of different weights, criteria, and preference functions (Geldermann and Zhang, 2001; Brans and Mareschal, 2005; Mareschal, 2014).

Examples of applications of PROMETHEE are Palma et al. (2007), who evaluated the integrated performance of silvoarable agroforestry on hypothetical farms, and Jactel et al. (2012) who analysed the ranking of forest management alternatives in the context of forest damage risk due to climate change. We follow Palma et al. (2007) and use the PROMETHEE II method (Brans and Vincke, 1985) as it enables the ranking of alternatives in a convenient and transparent manner.

2.2. Outranking Procedure of Adaptation Options

MCA outranking methods start from a decision matrix describing the performance of the alternatives to be evaluated with respect to identified criteria and focus on pair-wise comparisons of alternatives (Belton and Stewart, 2002). We denote the set of alternatives to be evaluated with $A = \{A_1, \ldots, A_i, \ldots A_m\}$ and the set of criteria with $C = \{C_1, \ldots, C_k, \ldots C_q\}$. Alternatives and criteria can then be expressed in an $m \times q$ evaluation matrix, in which each row describes an alternative and each column describes the performance of the alternatives for a specific criterion. On the basis of the evaluation matrix, the alternatives are compared in pairs in order to determine how one option is to be ranked relative to any other. A general characteristic of PROMETHEE is that all m alternatives are compared in a pair-wise manner, separately for each criterion. Let $f_k(A_i)$ be the score of climate adaptation option A_i under criterion k. Then, the preference score of two alternatives A_i and A_j is calculated using the preference function $P_k(A_i, A_j)$, $i \neq j$:

$$P_k(A_i, A_j) = \begin{cases} 0 \text{ if } f_k(A_i) - f_k(A_j) \leq 0 \\ 1 \text{ if } f_k(A_i) - f_k(A_j) > 0. \end{cases} \quad (1)$$

The uni-criterion net flow Φ_k indicates the performance of alternative A_i against all other alternatives for criterion k and is calculated as follows:

$$\Phi_k = \frac{1}{m-1}\left(\sum_j P_k(A_i, A_j) - \sum_j P_k(A_j, A_i)\right), \quad i \neq j. \quad (2)$$