Ecological Indicators 76 (2017) 366–375

Contents lists available at ScienceDirect

Ecological Indicators

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

Developing indicators for adaptation decision-making under climate change in agriculture: A proposed evaluation model

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ARTICLE INFO

Article history:
Received 31 March 2016
Received in revised form 19 October 2016
Accepted 6 December 2016
Available online 11 February 2017

Keywords:
Climate- extreme
Countermeasure
Feasibility
Effectiveness
Prioritization

ABSTRACT

This study proposes a new approach to developing a set of indicators for evaluating, prioritizing and choosing adaptation practices to climate change in agriculture. A simulation process is further conducted by applying the proposed indicators and the AHP model to prioritize adaptation alternatives to drought conditions. Data are collected through semi-structured questionnaires, focus group discussions, face- to-face interviews and literature review. Based on the focus group discussions, a six-step process is derived for use in developing indicators. A total of seventeen indictors are developed and classified into two broad components; feasibility and effectiveness (eight and nine indicators, respectively). The simulation results show that irrigation and drought- tolerant varieties are most feasible and effective alternative adaptation practices to drought in the Lawra district of Ghana. The proposed indicators are expected to provide a useful tool for supporting the decision-making process of stakeholders in the agriculture sector under climate change conditions.

1. Introduction

Climate change prediction models suggest that in Northern Ghana, the standard deviation for the onset of the rainy season will increase (Laux et al., 2008: 130). This infers that not only will the on-set of rainfall shift but also it will become even more erratic. Subsequent research findings have pointed to increasing incidences of extreme weather events (i.e. droughts, late rains, floods, decreasing annual precipitation and increasing temperatures) due to climate change (Yengoh et al., 2010; Stanturf et al., 2011). The implications are that, agricultural production will decline and the low food security and income conditions of the majority of people in Northern Ghana will worsen. Thus, under these prevailing effects of climate change on agriculture, choosing the most feasible and effective counter-measure or adaptation practice in any given season is crucial to boosting agricultural production. While choosing an appropriate climate adaptation strategy is pivotal to increasing crop production, selecting a wrong strategy can be detrimental to crop production and food security. The adoption process requires a series of decision-making by individuals. Before a technology is adopted, the individual must first be aware of its existence. After awareness, the technology may be rejected immediately or the adoption process may continue with the individual developing interest in the technology. The technology may be rejected after the initial interest or the individual may proceed to the next stage of comparing the technology with other existing practices. If the outcome is favorable, the technology would be not rejected but tested on a small scale to see if it works for them. The technology is then adopted if it passes the test (Etwire, 2012). Considering the current conditions of increasing environmental and economic vulnerability due to climate change, and the availability of various adaptation practices, the key question being constantly asked is; how can we determine the most feasible and effective adaptation practice to a predicted extreme weather event? To address this question, traditional and scientific approaches have basically been used in the past. The traditional approach of selecting adaptation strategies is based on farmers' own experiences and judgment with limited or no information on empirical weather forecast and scientifically verified and available adaptation options. The scientific approach involves two different methods. In the first method, researchers employ the farmers' perception index in which farmers use likert scale to assess various practices based on perceived importance (Uddin et al., 2014; Ndamani and Watanabe, 2015a). In the second method, adaptation practices are assessed based on economic cost. These approaches, to some extent do not address issues of feasibility and effectiveness with respect to adaptive capacity to the ecology, compatibility with societal norms and traditions, flex-

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http://dx.doi.org/10.1016/j.ecolind.2016.12.012
1470-160X/

ibility, and institutional capacity, availability and accessibility and weather forecast. The recent reports of increased variability in crop production due to climate change (MoFA, 2007) imply that existing approaches and methods are not effective. Thus, a technique is needed for a comprehensive assessment of adaptation practices to climate change in agriculture. The aim of this study therefore is to propose a new model for developing indicators for assessing adaptation practices to climate change in agriculture. By developing relevant indicators of feasibility and effectiveness, a decision making model could be applied to assess and select the most appropriate adaptation option.

Indicators are measures used to quantify or qualitatively describe phenomena that are not easily measured directly, but which society considers valuable to monitor over time. For many decades, indicators have been used to communicate information about complex systems or phenomena in a way that is relatively simple to understand. Indicators are useful for sharing the results of technical analysis or for monitoring characteristics of systems, such as fisheries, to inform public decisions (Boyd and Charles, 2006). In particular, indicators have become very useful in monitoring 'sustainable development' (WCED, 1987) —a complex and often ambiguous concept that cannot be measured directly. Also, a set of indicators have the potential to serve as a powerful decision-making tool for communities, businesses, policy makers, organizations and governments to reduce vulnerability and resource waste by assessing and identifying most feasible strategies based on stakeholders' perceptions. Standard of judgments, opinions and choices of people vary from one individual to the other. Peoples' preferences at any point in time are dependent on 'state of mind', current perceptions, past experiences, future expectations, environmental lifestyle, ecosystem ethic, the context of observation and tradeoffs. The most important issue therefore is how to use the large and varied perceived individual information (Hyman, 1980) to determined feasible and effective strategies

Literature shows that many methods exist for setting priorities in agricultural research. These include Mathematical Models, Scoring, Checklist, Rule of Thumb, Domestic Resource Cost, economic Surplus, Cost-Benefit, and Simulation (Braunschweig, 2000). Previous studies have found the 'scoring method' more useful to the complicated requirements related to the agricultural decision making process (Contant and Bottomley, 1988). Other findings have deemed a combination of the scoring method with other methods to be relevant in decision making (McGalla and Ryan, 1992; Collion and Gregory, 1993; Franzel et al., 1996). To avoid the limitations of the scoring method, the 'Analytical Hierarchy Process' (AHP) was suggested (Saaty, 1980) as a way to avoid the deficiencies of the scoring method while ensuring participation and transparency in line with a standard procedure. The AHP model is a powerful and flexible tool for decision-making. It allows decision makers to systematically evaluate various elements based on decision hierarchy tree by comparing them to one another in pairs. The decision makers can use concrete data about the elements, or they can use their judgments about the elements' relative meaning and importance (Saaty, 1980).

The AHP model has previously been applied to investigate management decisions in administrations; transportation planning, energy resource allocation, urban planning, setting priority for energy and environmental research projects, prioritization of electricity industries, design of renewable energy systems, identification of favorable fuels in transportation industries, evaluating machine tool alternatives and technology assessment (Ferrari, 2003; Ramanathan and Ganesh, 1995; Bose and Anandalingam, 1996; Kagazyo et al., 1997; Kablan, 1997; Chedid et al., 1998; Poh and Ang, 1999; Ayag and Ozdemir, 2006; Herkert et al., 1996). The model has also been used to investigate decisions in the agriculture sector (Alphonce, 1997). Literature has shown that the AHP model can help the farmer set priorities and make the best decision when both qualitative and quantitative aspects of a decision need to be considered (Pažek and Rozman, 2003). This study therefore proposes a new approach to developing indicators for evaluation of agricultural adaptation practices to climate change. The study also applies the AHP decision support model to determine the relative importance of the developed components and indicators. Further, the adaptation practices to drought in agriculture are also evaluated and prioritized for easy selection. Drought adaptation practices are used because findings of previous studies show that farmers in the study area generally adapt to drought and dry spell (Ndamani and Watanabe, 2015a).

Table 1
Adaptation practices and categorization.

Adaptation practice	Specific practices
Improved crop varieties	Use of drought-tolerant varieties
	Use of early maturing varieties
Crop diversification	Crop rotation
	Mixed cropping
	Change of planting date
Farm diversification	Mulching
Mixed farming	Composting
	Reduce land size
	Increase land size
	Integrated farming (crops and livestock/farming)
Agroforestry	Tree planting
Irrigation	Dry season gardening
	Dams and dug-outs
	Terracing and ridging

2. Materials and methods

2.1. The study area

The study location is the Lawra district of Ghana situated between longitude 10°30′ N and latitudes 2°35′ W. Lawra district lies within the Guinea Savanna Zone with mean annual rainfall ranging from 900 to 1200 mm. It has two seasons: dry season (November – April) and rainy season (May-October). The vegetation is characterized by shrubs and medium size trees, such as shea-tree, dawadawa, baobab, and acacia. The soils are laterite developed from the birimian and granite rocks. The district was selected because analysis of rainfall data from Ghana Meteorological Agency indicates that it is more susceptible to extreme weather conditions. Agriculture production is the main source of food and household incomes among its vast majority of rural households. The main crops produced are maize, sorghum, millet, and groundnut. Recurrent droughts, dry spells, and floods tend to have adverse effects on production of these crops. Farming is largely rain-fed. The sole dependence on an annual mono-modal rainfall pattern combined with limited farm resources make agriculture vulnerable to climate change impacts (Ndamani and Watanabe, 2015b).

In order to mitigate or adapt to these impacts and improve crop production, farmers in the district use various practices (Table 1). Overwhelming majority farmers classify drought-tolerant virilities, early maturing varieties, crop rotation, mixed cropping, mixed faming and change of planting dates as strategies meant to directly improve crop production under climatic variability. Mulching, composting, reduction of farm and increasing of farm size are adaptation strategies related to soil improvement.

2.2. Survey design and data collection

Focus group discussions (FGDs), face-to-face interviews, field observations and literature review were the main tools used in