CRIMSON PUBLISHERS
Wings to the Research

Environmental Analysis & Ecology Studies

ISSN 2578-0336

Review Article

Theoretical and Methodological Approaches to Climate Change Adaptation Assessment: Review Paper

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Submission: December 08, 2017 **Published:** May 11, 2018

Abstract

Conceptual explanation of adaptation by various scientific communities is inconsistent, causing misunderstanding in the climate change adaptation research that needs multidisciplinary approaches. This article presented the theoretical and methodological approaches of adaptation assessment. The needs for adaptation, proactive, reactive, spontaneous, planned, private and public adaptations have been identified. In addition, the broad categories of adaptation such as bear losses, share losses, modify the threat, prevent effects, change use, change location, research, and educate, inform and encourage behavioral changes have been also indicated. The General and Partial Equilibrium models are the two climate change adaptation assessment methods, the first of which deals with the whole parts of the economy whereas the second deal with a part of the economy comprising of the agro-economic-economic, cross-sectional, and the discrete choice models. Finally, it was found that the integrated adaptation assessment approach with the application of predictor variables is crucial method. Discrete choice models such as logit and probit models are essential for the study of perception and adaptation.

Keywords: Vulnerability; Climate change; Adaptation; Farming community

Introduction

Climate change has become a center of attention of the scientific community, policy-makers and civil society as they are increasingly aware that it is leading people to risk. However, conceptualization of the various scientific and practitioner communities are inconsistent, causing misunderstanding in the climate change adaptation research [1-6]. In order to address climate change-induced impact, assessing the climatic conditions, the vulnerable systems, people's perception, and adaptation mechanisms in a given society is essential. For doing so, identifying theories and methods relevant to the assessment of climate change adaptation is the current concern of many international, regional, national and local communities. Therefore, this article reviews the theoretical, methodological and empirical literatures on perceptions and adaptation to climate change. Besides, it identifies the alternative adaptation strategies.

This article was prepared based on review of a set of articles, reports, discussion papers, Guidebooks, theoretical and empirical in nature-written over the past years to examine the effects of climate change on natural and human systems. The main concern was on the theoretical approaches, analytical methods, and empirical findings used for the assessment of adaptation to climate change. The review was not a simple citation of materials, instead the cited sources were reviewed, critically evaluated, commented, and best methods were suggested for future uses.

Adaptation to Climate Change

The two fundamental societal response options to the risks posed by anthropogenic climate change are mitigation and adaptation to climate change [7]. In the climate change context, mitigation means limiting global climate change by reducing the emissions of greenhouse gases and enhancing their sinks [8]. Adaptation means actions targeted at the vulnerable system in response to actual or expected climate stimuli with the objective of moderating harm from climate change and exploiting opportunities brought about by climate change [9].

The Need for Adaptation to Climate Change

Adaptation is an essential component of climate change impact and vulnerability assessment, and is one of the policy options in response to climate change impacts [10]. Indeed, the important role of adaptation as a policy response by governments has been recognized internationally. Article 4.1b of the United Nations Framework Convention on Climate Change (UNFCCC) states that parties are committed to formulate and implement national and, where appropriate, regional programs containing measures to mitigate climate change and to facilitate adequate adaptation to climate change. The Kyoto Protocol (Article 10) further commits parties to promote and facilitate adaptation, and deploy adaptation technologies to address climate change [11].

There are convincing arguments for a more comprehensive consideration of adaptation as a response measure to climate change. First of all, anthropogenic greenhouse gas emissions are already affecting average climate conditions and climate extremes which can no longer be prevented even by the most ambitious emission reductions [7,9]. For example, twelve of the thirteen warmest years globally occurred between 1995 and 2007 [12]. Even the relatively small magnitude of climate change observed so far has considerable impacts on many natural and social systems. Second, climate will continue to change for the foreseeable future as a result of accumulation of greenhouse gases emitted in the past and the inertia of the climate system, the rate of global warming in the next few decades is projected to be substantially faster than in the last few decades, largely irrespective of the emission scenario [13]. Third, the effect of emission reductions takes several decades to fully manifest, whereas most adaptation measures have more immediate benefits. Fourth, adaptations can be effectively implemented on a local or regional scale and its efficacy is less dependent on the action of others, whereas mitigation of climate change requires international cooperation, such that their efficacy is less dependent on the actions of others. Fifth, most adaptations to climate change also reduce the risks associated with current climate variability, which is a significant hazard in many world regions [9,10]. Finally, many measures undertaken to adapt to climate change have important ancillary benefits, for example reducing current climate-sensitive risks [7].

The increasing interest in adaptation to climate change is reflected in the development of the theory and practice of climate change assessments, and in increasing consideration by political organizations and funding bodies [7,9]. Many potential adaptation options have been suggested for the agrarian community to alleviate expected adverse impacts of climate change. They encompass a wide range of forms (technical, financial, managerial), scales (global, regional, local) and participants (governments, industries, farmers) [8,14]. Most of these represent possible or potential adaptation measures, rather than ones actually adopted. Climate change impact analyses often assume certain adaptations, although the adaptation process itself remains unclear [10]. There is a need to understand what types and forms of adaptation are possible, feasible and likely; who would be involved in their implementation; and what is required to facilitate or encourage their development or adoption. A necessary first step in addressing these concerns is the identification and characterization of adaptation options in the agrarian community [15]. Effective adaptation to climate change is contingent on the availability of two important prerequisites: information on what to adapt to and how to adapt, and resources to implement the adaptation measures [9]. The collection of information about the vulnerable system and the stressors that it is exposed to, and the transfer of resources to vulnerable societies in order to help them to prepare for and cope with unavoided impacts of climate change are thus necessary elements of a comprehensive climate policy [16]. These measures may either be categorized as actions that facilitate adaptation or as separate response options.

Types of Climate Change Adaptation

Adaptation assessment is the practice of identifying potential adaptations to climate change impacts [11]; perception of people on climate change, and barriers of adaptation. The aim is to suggest adaptation strategies that can reduce the vulnerability of places and sectors to climate change at present and in the future. Typology and current knowledge of adaptation options to climate change for the agrarian community from studies of vulnerability to climate change impact and adaptation have been reviewed. The following adaptations types are identified by Smit et al. [10] and IPCC [13].

Reactive versus proactive adaptations

Adaptation can be said to be reactive or proactive based on stimulus (motivation) - whether an action is in response to observed climate impacts, or in anticipation of future climate change. Reactive adaptation takes place after impacts of climate change has been observed or felt. This is also known as ex-post adaptation. As reactive adaptation is informed by direct experience, resources can be targeted to known risks. In this sense, adaptation historically has been largely but not entirely reactive [17,18]. On the contrary, proactive adaptation takes place before the impacts of climate change are observed or felt. This type of adaptation is also known as anticipatory adaptation. Proactive adaptation, unlike reactive adaptation, is forward-looking and takes into account the inherent uncertainties associated with anticipating change. Therefore, in addressing future risks, uncertainties in the extent, timing, and distribution of impacts make it harder to determine the appropriate level of investment, exactly what measures are needed, and when [18]. Adaptation can also be considered as reactive or proactive in form. Here, the distinction concerns on the nature of society's response [10]. A proactive approach aims to reduce exposure to future risks, for instance, by avoiding development on flood-prone lands (change location); a purely reactive approach aims only to alleviate impacts once they have occurred, for instance by providing emergency assistance to flood victims (share losses). Experience suggests that proactive adaptation requires a greater initial investment but is more effective at reducing future risk and cost [18]. Therefore, adaptation strategies should give priority to proactive actions reducing future risk, but as risks will remain, reactive approaches also help vulnerable populations recover from unavoidable impacts.

Autonomous versus planned adaptation

Autonomous adaptation (also referred to as spontaneous adaptation) does not constitute a conscious response to climatic stimuli but is triggered by ecological changes in natural systems and by market or welfare changes in human systems. Planned adaptation on the other hand, is the result of a deliberate policy decision, based on an awareness that conditions have changed or are about to change and that action is required to return to, maintain, or achieve a desired state [10,18].

How to cite this article: Menberu T. Theoretical and Methodological Approaches to Climate Change Adaptation Assessment: Review Paper. Environ Anal Eco stud. 2(4). EAES.000541.2018. DOI: 10.31031/EAES.2018.02.000541

Private versus public adaptations

Private adaptation is initiated and implemented by individuals, households or private companies usually in the actor's rational self-interest while Public adaptation is initiated and implemented by governments at all levels usually directed at collective needs [17,18]. The question of how adaptations occur refers both to the processes and the forms of adaptation. These processes and forms of adaptation are not independent of who or what adapts? and adaptation to what? For example, adaptations in unmanaged natural systems are necessarily autonomous and reactive, whereas adaptations initiated by public agencies are usually planned and may be anticipatory [10]. In Ethiopia, both household and public level climate risk management through mitigation and coping practices are undertaken to reduce the damages from climate change. Adaptation strategies at household level include crop diversification, mixed crop and livestock production; keeping multiple species of livestock; and joining rotating credit groups. Coping strategies at household level include selling productive assets; selling of livestock and agricultural products; reducing current investment and consumption; child labor; temporary and permanent migration; mortgaging of land; and use of inter-household transfers and loans [19]. Public level risk mitigation strategies include: water harvesting and irrigation; resource conservation; and management; voluntary resettlement programs; extension packages; agro-ecological packages; productive safety net programs; and the newly pilot studies (namely weather-indexed drought insurance and commodity exchange program). Coping strategies include: free food distribution and food for work programs (Mo FED, 2008). Food aid has become one of the most important coping strategies to fight drought and famine. Types of adaptation discussed above can fall either in one or more of the following eight common categories except bearing losses [20].

Bear losses

This refers to response of doing nothing except bearing or accepting the losses when the affected groups have no capacity to respond or where the costs of adaptation measures are very high in relation to the risk or the expected damages. This category is not applicable in the real world as societies can take at least one action at times of climatic disaster.

Share losses

This type of adaptation response involves sharing the losses among a wider community both in traditional and most complex, high-tech societies. In traditional societies losses have been shared through extended families in villages and small-scale communities (autonomous adaptation). On the other hand, large-scale societies share losses through public relief, rehabilitation, and reconstruction paid from public funds through private insurances (Planned public adaptation). This category mostly falls in the reactive adaptation.

Modify the threat

Are actions that provide adaptation benefits by exercising a control over the environmental threat such as drought and floods through possible measures like flood control works (dams, dikes, levees) to protect low-lying coastal areas from rising waters, soil conservation structures, planting trees, reducing evaporation from ponds through improved shading and so forth. This can be either reactive or proactive adaptation based on the time of intervention; or planned or autonomous, private or public. If the intervention is after the occurrence of a flood it can be reactive and if the work is done in anticipating future occurrence, it can be proactive.

Prevent effects

This is preventing the effects of climate change and variability through changes in crop management practices such as increased irrigation water, additional fertilizer, and pest and disease control. This category is related to agricultural technology adoption and institutional capacity. Establishment of early warning systems for flooding or heat waves, or introduction of heat- or drought-resistant crop varieties can also be typical examples.

Change use

These actions are undertaken when the threat of climate change makes the continuation of a given activity impossible or put at extremely risky situation. For example, a farmer is able to shift to different crops or livestock that are better suited to changing climatic conditions. Similarly, crop land may be returned to pasture or forest or other uses may be found such as recreation, wildlife refuges, or national parks.

Change location

This category is the most extreme response, for example, relocating major crops and farming regions away from areas of increased aridity and heat to areas that are currently cooler and attractive for some crops in the future.

Research

The process of adaptation can also be advanced by research into new technologies and new methods of adaptation. This may be related to the research works undertaken by agricultural research institutions and biodiversity or environmental protection agencies which are responsible to find more productive, pests and disease as well as drought resistant crop and livestock varieties. They are also doing to keep genetic resources for sustainable uses.

Educate, inform, and encourage behavioral change

This is the dissemination of knowledge through education and public information campaigns, leading to behavioral change. Such activities have been little recognized and given little priority in the past, but are likely to assume increased importance as the need to involve more communities, sectors, and regions in adaptation becomes apparent [20].

Determinants of adaptation to climate change

Several studies on climate change impact and vulnerability have proposed various adaptation options for the farming community. For example, [21] in 11 countries of Africa; [19,21,22] in Ethiopia identified different adaptation strategies. The most common adaptation method used by almost all countries (except Cameroon and South Africa) was planting different crop varieties. They also identified soil conservation, water harvesting, and change planting

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dates (early or late), change crop variety, off-farm activities, migration, change farming type (from crop to livestock and vice-versa), and adoption of new technologies.

Mertz et al. (2008) also pointed out that using crop varieties mostly vegetables; keeping animals in stables; replacing draught horses with cattle, which are cheaper to feed; and using manure as the main adaptation strategies to counter perceived climate impacts on agricultural production in the Sahel region of Africa. Use of irrigation as an adaptation option was reported only by 5% of the respondents among the other adaptation methods identified in the Blue Nile Basin. About 42% in Temesgen et al. [23] and 49.4% in Yesuf et al. [24] of surveyed respondents did not employ any adaptation methods. In this regard, Burton et al. [18] and NMSA [25] recognized different determinants of farmers' adaptation choices such as a society's level of wealth, education, institutional strength, and access to technology, poverty, and low environmental awareness. The reasons mentioned by the surveyed farmers are nearly consistent with these factors. Lack of information on climate change impacts and adaptation options, lack of financial resources, labor constraints, and land shortages were reported as the major determinants of adaptation. Lack of financial resources constrains farmers from accessing the necessary technologies for adaptation. For instance, there is abundant water resource in the Nile Basin, but poor farmers cannot afford to invest in irrigation technology for adaptation or sustain their livelihoods during climatic extremes, such as drought. Poor farmers are often unable to mobilize sufficient family labor or hired labor for adaptation. Increasing population forces farmers to intensively cultivate small plots of land, making it difficult for adaptation practices, such as planting trees that require more land [21,24].

Household characteristics such as the level of education, sex and age of the household head, and household size are assumed to increase the probability of adaptation. Greater access to information on climate change, improved technologies, and higher productivity are acquired through higher level education. [21] and Temesgen's et al. [24] studies asserted that education increases climate change awareness and the likelihood of soil conservation and changing planting dates. However, Maddison's [21] study did not indicate whether the differences between the views of experienced and inexperienced farmers are statistically significant. Nor does it indicate whether the results are sensitive to other factors. Male-headed households are found to be more likely to adapt to climate change in Ethiopia given that men do much of the agricultural work and are more likely to obtain information on climate and new technologies. The age of the household head, which captures farming experience, also influences awareness of, and adaptation to climate change. Access to credit, crop and livestock extension services, and information about climate change, also increases the use of adaptation options. The studies confirm that there is a positive relationship between level of adoption and access to credit. Access to credit relieves cash constraints for purchasing inputs such as fertilizer, improved crop varieties, and irrigation facilities. Access to crop and livestock extension significantly increases the likelihood of adaptation. Social networks play distinct roles in adoption of agricultural technologies: they act as conduits for financial transfers that may ease farmers' credit constraints, provide information about new technologies, and facilitate cooperation among farmers to allow the costs and benefits of adaptation to be shared. Temesgen [19] confirms that social networks measured by the number of relatives living in the area and access to farmer-to-farmer extension increase awareness of climate change and likelihood of adaptation.

Farm location, local temperature, and the amount of precipitation also influence farmers' adaptation to climate change in the Nile Basin. Farmers living in different agro-ecological settings employ different adaptation methods. For instance, lowland farmers are more likely to conserve soil but less likely to use different crop varieties, to plant trees, or to irrigate compared with midland farmers. Further, while highland farmers are more likely to perceive changes in climate than midland farmers, those in the highlands are less likely to plant trees [24]. Farms located in areas with higher annual mean temperatures were more likely to adapt to climate change. Higher annual mean temperature increases the likelihood of employing soil conservation methods, using different crop varieties, changing planting dates, and irrigating. Similarly, lower levels of precipitation increased the likelihood of adopting adaptation techniques specifically, using soil conservation methods, changing crop varieties, changing planting dates, and irrigating. These results suggest that as the temperature rises and conditions become drier, farmers employ methods to preserve soil moisture to ensure that their crops survive [24].

According to Maddison [21] different planting dates are also important adaptation practices in Egypt, Kenya and Senegal. Adopting a shorter growing season is universally practiced in Senegal but is almost irrelevant elsewhere. In Egypt the majority of respondents have practice non-farming activities while in Egypt, Kenya and South Africa significant numbers of farmers have increased use of irrigation. There is increasing use of water conservation techniques in Burkina Faso, Kenya and Niger. In Burkina Faso, Kenya, Senegal and Niger soil conservation techniques are increasingly practiced. There is increasing use of shading and sheltering techniques in Burkina Faso, Niger and Senegal approximately adopted by a third of respondents. Increased use of weather insurance is almost exclusive to Egypt. Prayer and ritual offerings are also made in Senegal and Niger. There are however, several countries in which almost a third or more of respondents report no change in agricultural practices. These include Burkina Faso, Cameroon, Ghana, South Africa and Zambia. By contrast every Egyptian and every Ethiopian respondent claimed to have made at least one adaptation.

The similarity among the reviewed studies is that all studies addressed perception of climate change and types of adaptation. But Mertz et al. (2008) and Yesuf et al. [22] did not identify determinants of farmers' perception of climate change while others did. Rather they identified the causes of climate change from the perspectives of farmers' perception. Yesuf et al. [22] differs from

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other studies in that besides estimating the determinants of adaptation to climate change, they estimated the implication of these strategies on farm productivity. They also interpolated the specific rainfall and temperature values to individual households using thin plate spline spatial interpolation method. The finding reveals that climate change and adaptation strategies have significant impact on agricultural productivity.

In order to mitigate the challenges of climate change and associated extreme events, appropriate institutional arrangement and policy directions are necessary. Accordingly, Hezri et al. [26] noted the necessity of appropriate institutional settings and adaptation policy interventions across multiple sectors. The policy processes and institutional systems should support cross-sectoral integration, vertical coordination, capacity building and devolution, evaluation and awareness creation. This literature noted that adaptation does not simply occur independently at the field or farm level, but it is a process greatly influenced by broader economic, political and social forces. In addition, policy initiatives by governments represent adaptations for the sector as a whole. The role of government policies, institutional arrangements, and macro-level social and economic conditions is increasingly recognized in adaptation studies.

Methods to Assessing Adaptation to Climate Change

The fact that climate change adaptation research is a recent phenomenon, researchers on the field traced their methodologies from agricultural technology adaption because of the methodological similarities [21,23]. Agricultural technology adoption models are based on farmers' utility or profit maximizing behaviors [21]. The assumption here is that farmers adopt a new technology only when the perceived utility or profit from using this new technology is significantly greater than the traditional or the old method. However, their capacity also constrained them to adopt new technologies. Madison [21] noted that African farmers have been constrained by different factors to adopt climate change adaptation strategies. The economy-wide (General equilibrium) and the partial equilibrium models are identified to analyze adaptation to climate change.

Economy-wide models

The economy-wide models are analytical models frequently deal with the economy as a complete system of independent components (industries, factors of production, institution and the rest of the world) [23]. This means, these models are employed to analyze impact of and adaptation to climate change at national or global levels. For instance, You et al. [27] studied the potential threat of climate change to the Ethiopian economy and recommended enhanced investment on water control to expand irrigation and improve flood protection in order to adapt to these long-term changes in Ethiopia.

Yu et al. [28] also estimated the impacts of climate change on agricultural and water systems in Vietnam. The results indicate that the severity of climate change impact on rice production is spatially differentiated and hence he suggested localized policy packages of adaptation to minimize substantial regional variations in impacts. Mendelsohn et al. [29] also analyzed the potential effect of climate change on African Agriculture. The result concluded that African agriculture is very vulnerable to climate change and the potential damages may be large both in absolute terms and as a fraction of agricultural gross domestic product (GDP). Although the economy-wide model can analyze the impacts of climate change on the complete system of the economy, there are limitations. Key limitations include difficulties in model selection, parameter specification and functional forms, data consistency or calibration problems, the absence of statistical tests for the model specification and the complexity of the CGE models and the high skills needed to develop and use them [21,30].

Partial equilibrium models

Partial equilibrium models are based on the analysis of part of the overall economy such as single market (single commodity) or sub-set of markets or sectors [19,24]. Three methods have been identified under partial equilibrium models for analyzing climate change adaptation. These are agronomic-economic, cross-sectional and discrete choice models which are compared and discussed further in detail as follows.

The agronomic-economic method

This method is used to analyze the impact of climate change on agriculture based on the suitability of various land and biophysical attributes for crop production. Crop characteristics, existing technology, soil conditions, and climate factors are included. By doing so, the model can identify the suitable lands for crop production and predict the impact of climatic variables on potential agricultural outputs and cropping patterns [19,24]. This method did not consider socioeconomic and political factors. Maddison et al. [21] analyzed the economic impacts of climate change on agriculture and the farming communities in Africa, based on both the cross-sectional (Ricardian) method and crop response simulation modeling. The cross sectional analysis allowed for assessing the possible role of adaptation. Moreover, they employed river-basin hydrology modeling to generate additional climate attributes for the impact assessment and climate scenario analyses.

Mendelsohn et al. [31] examined country-specific market impacts of climate change by combining Global Impact Model (GIM), and the Ricardian method. Country-specific results indicate that the 2 °C global-mean warming projected for 2060 will result in net market benefits for most Organization for Economic Cooperation and Development (OECD) countries and net market damages for most non-OECD countries. The possibility that impacts may systematically differ among the countries is likely to be important to international agreements on climate-change policy. This demonstrates the importance of developing country-specific response functions to improve the science and inform the policy debate. But the study has several limitations:

a) The response functions except tourism were calibrated only for the United States;

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b) The non-climate information about each country is not extensive;

c) Non-market effects are not included;

d) The simulated climate changes are due only to increased CO_2.

Nevertheless, the results of this study show that the impacts of climate change will likely not be uniform from country to country and suggest establishment of successful international cooperation for adaptation [32]. Adaptation to changing climatic conditions can be addressed within agronomic-economic method by generating comparative static scenarios with changes in technological parameters. The disadvantage of this method is that it is not possible to predict final outcomes without explicitly modeling all the relevant components and thus the omission of one major factor would substantially affect the model's predictions [32].

Cross-sectional methods

The Ricardian model is the most widely used cross-sectional method to analyze the impact of climate change by incorporating adaptation under different climatic conditions [32]. This model has been applied to value the contribution that environmental factors make to farm income by regressing land values on a set of environmental inputs and thereby measuring the marginal contribution that each input makes to farm income. Net revenue or price of land can be used to represent farm income. Seo et al. [33] analyzed the economic impacts of climate change on agriculture and the farming communities in Africa using Ricardian method. Moreover, they employed river-basin hydrology modeling to generate additional climate attributes for the impact assessment and climate scenario analyses such as surface runoff and stream flow for all districts in the study countries. Kurukulasuriya et al. [34] adopted the Ricardian method to examine the impact of climate change on cropland in 11 African countries. The results show that net revenues fall as precipitation falls or as temperatures warm across all the surveyed farms and all countries are not equally vulnerable to climate change. Seo et al. [35] also examined the distribution of climate change impacts across the 16 agro-ecological zones in Africa by regressing net revenue per hectare of cropland on a set of climate, soil, and socio-economic variables. They indicated that country fixed effects slightly reduce predicted future climate related damage to agriculture. African farmers gain income from climate change with mild climate scenario; with a more severe scenario, they lose income. The analysis of agro-ecological zones implies that the effects of climate change will vary across Africa.

The most important advantage of the Ricardian model is its ability to incorporate private adaptations. Farmers adapt to climate change to maximize profit by changing the crop mix, planting and harvesting dates, and a host of agronomic practices. The farmers' response involves costs, causing economic damages that are reflected in net revenue. Thus, to fully account for the cost or benefit of adaptation the relevant dependent variable should be net revenue or land value (capitalized net revenues), and not yield. Accordingly, the Ricardian approach takes adaptation into account by measuring economic damages as reductions in net revenue or land value. The other advantage of the model is that it is cost effective, since secondary data on cross-sectional sites can be relatively easy to collect on climatic, production and socioeconomic factors [24,34]. The weaknesses of the Ricardian method are: it is not based on controlled experiments across farms and may not include all factors. It also does not analyze price and carbon fertilization effects [29]. The most important disadvantage is its reliance only on cross-sectional data. Both the agronomic and Ricardian methods do not include analysis of perception of climate change and determinants of the choice of adaptation methods. Hence, these methods will not used in this study.

Discrete choice models

Logit and probit models are the most commonly used empirical models to analyze climate change adaptation. Binary logit and probit models will be employed when the number of choices available are two (whether to adopt or not) multinomial logit (MNL) and multinomial probit (MNP) models when the number of choices are more than two [21] For example, Nhemachena et al. [36] for analyzing determinants of the choice of climate change adaptation in South Africa. Similarly, Seo et al. [33] used the multinomial logit model to analyze how the choice of livestock species is climate sensitive. Gbetibouo et al. [37] used Heckman's probit model and a multinomial logit (MNL) model to examine the determinants of adaptation to climate change and variability. Nhemachena et al. [36] analyzed determinants of farm-level climate adaptation measures in Africa. The results indicate that specialized mono-cropping is most vulnerable to climate change in Africa and encouraged irrigation, multiple cropping and integration of livestock. Better access to markets, extension and credit services, technology and farm assets are critical for helping African farmers adapt to climate change.

Temesgen et al. [24] used the multinomial logit model to analyze the determinants of farmers' Choice of adaptation methods and perceptions of climate change in the Nile Basin. The result indicated that farmers adapted to climate change by using different methods. Those who did not use any of the methods described lack of information on adaptation methods and lack of money as major constraints to adaptation. The discrete choice models such as logit and probit models are selected for this study because they can analyze farmers' perception of climate change, determinants of their perception; identify adaptation strategies and the factors affecting the adoption of adaptation methods [38-40].

Summary

This article presented the theoretical and methodological approaches to adaptation assessments. The needs for adaptation to climate change and types of adaptation such as proactive, reactive, spontaneous, planned, private and public adaptations have been discussed [41-44]. In addition, the eight broad categories of adaptation such as bear losses, share losses, modify the threat, prevent effects, change use, change location, research, and educate,

inform and encourage behavioral changes have been also indicated. Emperical literatues on perception and adaptation have been reviewed [45,46]. Here determinats of adaptation choices have been presented mostly focusing on African and Ethiopian cases.

The different methodological approaches to analyzing adaptation to climate hazards have been discussed. In this case two methodological approaches are identified. These are the General and Partial Equilibrium models. The first most frequently deal with whole parts of the economy whereas the second deal with a part of the overall economy. The partial equilibrium models include: the agro-economic-economic, cross-sectional, and the discrete choice models. Accordingly, the article suggests the use of integrated adaptation assessment approach with the application of predictor variables is crucial. Discrete choice models such as logit and probit models are crucial to analyze adaptation to climate change.

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How to cite this article: Menberu T. Theoretical and Methodological Approaches to Climate Change Adaptation Assessment: Review Paper. Environ Anal Eco stud. 2(4). EAES.000541.2018. DOI: 10.31031/EAES.2018.02.000541

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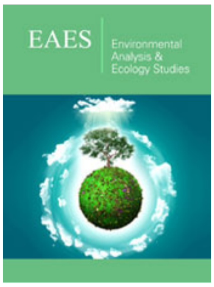

How to cite this article: Menberu T. Theoretical and Methodological Approaches to Climate Change Adaptation Assessment: Review Paper. Environ Anal Eco stud. 2(4). EAES.000541.2018. DOI: 10.31031/EAES.2018.02.000541