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Article *in* Journal of Tropical Agriculture · November 2023

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Climate Change Adaptation: A Global Review of Farmers Strategies

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Received 15 December 2022; received in revision form 12 April 2023; accepted on 17 May 2023

Abstract

Building an effective agricultural adaptation strategy is imperative to ensure food security in a world challenged by climate change constraints. Government and private individuals worldwide have been adopting short and long- term response strategies to cope up with erratic climate change impacts. Crop and livestock diversification, altering or optimizing planting dates, land, pest and nutrient management decisions, insurance and temporary migration were identified as the popular short-term adaptation measures among farmers around the globe irrespective of the agro-ecological zone they belong to. Capital intensive long- term adaptation strategies like Changing crop type and location, modernization of farm and practicing novel technologies, improved water management practices and permanent migration of labour were adopted by farmers, though on a limited scale. A rational, pragmatic and cost-effective method to deal with the possible outcomes associated with sudden or gradual climate scenarios is the implementation of sustainable agricultural policy in conjunction with concerted climate change adaptation strategies.

Keywords: Adaptation strategies, Agriculture, Climate change, Climate variability, Long- term strategies, Short- term strategies.

Introduction

There is no dispute that the global climate is changing. Observable changes in several extreme weather and climate events have been happening since about 1950s. A number of these changes are found anthropogenic (McCarthy et al. 2001, Karl and Trenberth 2003, Oreskes 2004), including an increase in extreme heat, international water level and number of heavy precipitation events and a decrease in cold temperature extremes (IPCC 2014).

"Last three decades have been warmer at the earth surface than any prior decades since 1850. The linear trend analysis of earth's average total surface temperature information from 1880 to 2012 shows a warming of 0.85 ^{o} C IPCC 2014). The global temperature was increased by 1^{o}C above pre industrial levels, with a plausible scope of 0.8^{o}C to 1.2^{o}C due to human activities. It is assessed that global warming could reach 1.5^{o}C between 2030 and 2052, if it continues with the same trend (IPCC 2018). At this stage of climate change, the adaptation capacity of an individual or a society, prone to the effect of climate change is of enormous importance.

Research on climate change has a long tradition for decades. A challenging problem in this domain is adapting to climate change. Climate change adaptation must be addressed in several areas of human activity. It is a major knowledge -intensive and multi-sector decision- making problem that needs a shift in how we organize our economy and society.

Previous studies have well established that agriculture is vulnerable to climate change (Fuhrer et al. 2006, Morton 2007, Nelson 2009). One of the major factors which decide the future food security of mankind would be the impact of climate change

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on agriculture and to what extent farmers could adapt to it. Moreover, agriculture being one of the drivers of climate change, it is necessary to have adaptation strategies which have a mitigation effect too. Erratic impacts of climate change on agriculture have become an obstacle to building a sustainable and resilient food system with assured food security. To create a more climate-resilient agricultural system, it is imperative to assist farmers and other stakeholders with adaptation practices that can vanquish the negative impacts of climate change. Agricultural productivity around the world, especially in developing countries of the tropical region, has been constrained by technical, resource and institutional factors (Mendelsohn and Dinar 1999). This existing vulnerability will be critical in the light of climate change, which makes part of the population engaged in agriculture and related businesses more susceptible to poverty.

Changes in land and water regimes appear as primary conduits of change that influence the agriculture sector directly. Universally appearing climate change impacts are frequent and intense rainfall, flooding followed by a long spell of drought, storm and cyclone damage, sea-level rise, pest and disease outbreak on crop and livestock, deteriorating soil conditions and so on (UNFCCC 2007, IPCC 2007, IPCC 2013). As a result, a reduction in agricultural productivity is being noticed in accordance with the degree of climate change impact on a particular spatiotemporal dimension. Such short- term to irreversible impacts of climate change can be addressed through an inclusive policy dialogue considering adaptation strategies. At the same time, poorly designed policies will increase the chances of maladaptation should be a concern for policymakers. Keeping these issues in mind, this paper points a research question 'Is there any adaptation strategies practiced by the farmers with respect to climate change and If so, how effective are those strategies?' Hence, this review paper focuses on literature discussing farmers adaptation strategies to climate change and variability around the world and how effective is a response strategy as a climate change adaptation measure. Adaptation practices which include not only the changes in crop varieties or switching to different crops, other adoption practices like changes in agronomic practices, adoption in soil and water conservation, etc. were also included depending on the area/region of the study to get a holistic view of the adoption practices followed by the farming community at the global level.

Materials and Methods

We had systematically reviewed the literature regarding the selected arena to synthesize scientific evidence. The research question was broken down into 1) identification of farmers' adaptation strategies to climate change and variability, and 2) effectiveness of farmers' responses as climate change adaptation strategies. The literature was screened for relevance using few essential criteria, which include 1) relevant subjects like agricultural adaptation strategies to climate change and variability, countries and regions around the continents, 2) type of extreme climate events and 3) outcomes of strategies. Initial filtering was based on the title, followed by abstract. The full text was reviewed for articles and reports that cleared the above-mentioned criteria.

Google scholar and Web of Science search engines were used to identify the peer-reviewed journal articles in Dec. 2019 to Feb. 2020. Around 145 articles were collected and among that 48 articles were excluded as those articles were primarily focusing on other aspects of climate change adaptation like factors influencing adaptation. Article selection process was illustrated on Fig. 1.

Results and Discussion

Climate change and variability: A global review of Farmers' adaptation strategies and effectiveness of farmers' responses

The impact of climate change is in sight across all continents and oceans. Evidence of this impact is more visible in natural systems. Studies carried out across the continents and crops revealed that climate

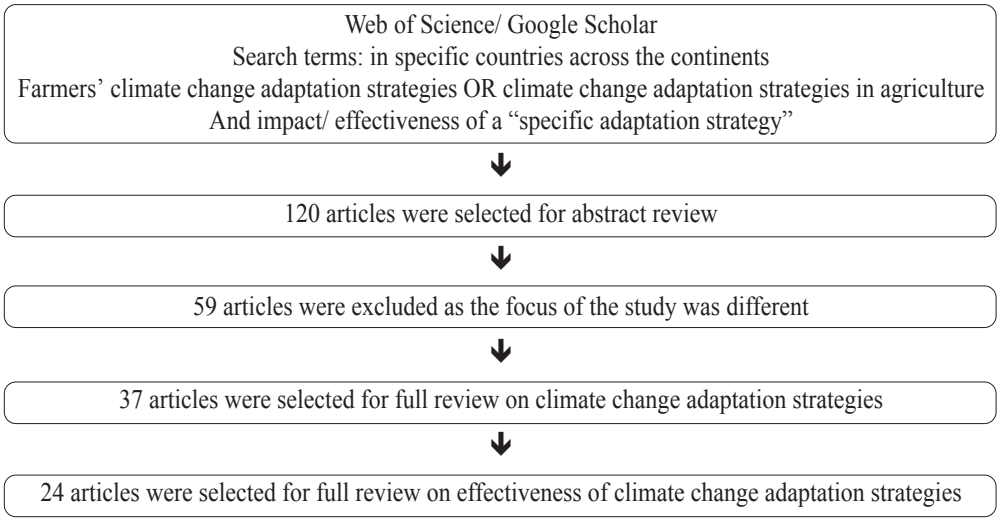

Figure 1. Overview of the systematic literature review

change's negative impact on the yield of crops outweighs its positive impacts. The adverse effects of climate change are more prevalent in wheat and maize than in rice and soybean when analyzed for main production regions and global aggregate. The climate change impacts on crop yield is a major constraint to the production aspects of global security than other components of food security (IPCC 2014).

The inherent link that agriculture has with natural resources makes it more susceptible to the effects of climate change. Apart from natural resources, the agricultural sector has been driven by factors like regional and international agricultural policies, market dynamics, type and availability of agricultural technology and extension services. In the recent past, climate change has been recognized as an additional factor that causes a spatiotemporal impact on agricultural productivity (Gornall et al. 2010). Farming societies worldwide have been adjusting to climate variability and change throughout history. Thus, adaptation has become an inevitable part of agricultural policy with ever-increasing climate change issues.

Review of farmers' adaptation strategies to climate change- Global studies

Refer Table 1 to 6

Effectiveness of farmers' responses as climate change adaptation strategies- Shreds of evidence from the literature

In the Asian and African continents, it is found that the majority of strategies, as a response to climate variability, were focusing on short term adaptation. Mostly, though not exclusively, the impact caused by climate variability was of short- term concern. Asian and African farmers widely practiced crop and livestock diversification as a short-term, farm-level response strategy. Replacement of generally grown varieties or breeds with high yielding varieties or animal breeds intended for higher drought or heat tolerance, planting different crops and adopting integrated farming systems were recognized as few of the popular farm level response strategies. Climate change is a threat to both biotic and abiotic elements. It is observed that agroecosystems with more diversified traits are less prone to effects of changing environmental scenarios (Matson et al. 1997, Altieri 1999). Diversified agroecosystems were found to have effective pest suppression (Rea et al. 2002), disease suppression (Zhu et al. 2000), increased production stability (Di Falco and Perrings 2003) and climate change buffering (Tengo and Belfrage 2004) which insulates the system from the effects of climate change and variability.

Table 1. Review of farmers' adaptation strategies to climate change for Africa, as reported in the literature

Country/Province	Reference	Adaptation strategies
South Africa	Benhin 2006	To adapt to rising temperatures: use water-efficient, heat-tolerant crops, early-maturing varieties, and mixed farming. To cope with heavy rainfall: delay planting, harvest early, and create water harvesting furrows. Other strategies include applying chemicals to reduce evapotranspiration, using mulch to retain soil moisture, buying insurance for farms, and diversifying income through non-farm activities.
Africa	Maddison 2007	Adaptation strategies used in different countries of Africa include: using different crop varieties, varying planting dates, shortening growing seasons, diversifying income through non-farming activities, increasing irrigation and water conservation, implementing soil conservation methods, and using shading and sheltering techniques. Weather insurance is also being utilized.
Ghana	Fosu- Mensah et al., 2010	To adapt to a warmer climate and declining precipitation: farmers can diversify the crops they grow and adjust planting dates.
Nigeria	Ofuoku 2011	Adaptation strategies commonly used include: planting trees, soil conservation, adjusting planting dates, cooling livestock pens with fans, using heat-tolerant species, irrigation, and growing different varieties of crops.
Northern Nigeria	Tiamiyu et al., 2017	• Climate-smart agronomic practices include cultivating early-maturing, drought-tolerant, pest/disease-resistant varieties, intercropping with cover crops, agroforestry, Integrated Pest Management and Integrated Soil Fertility Management through the use of farmyard manure and microdosing of fertilizers. • Climate-smart water management practices were building terraces on sloping farmland, mulching, controlled flooding before and during cultivation and using drip and sprinkler irrigation.
Ethiopia	Wolka and Zeleka, 2017	Institutional climate change adaptation strategies include selling assets such as livestock, seeking government aid, taking up off-farm employment, reducing consumption, using credit services and diversifying food sources. Crop and land management strategies to adapt to climate change involve using tolerant crop varieties, adjusting planting times, and planting fast-growing varieties.
North-West Ethiopia	Asrat and Simane 2018	Agronomic adaptation practices include: crop rotation, intercropping, adjusting planting dates, diversifying cropping systems and implementing soil and water conservation practices.
Ethiopia and Nigeria	Oranu et al., 2018	Adaptation practices widely used were: using improved seeds, implementing water harvesting and soil moisture conservation techniques, modifying grazing practices, altering fertilizer application methods, diversifying cropping systems, shifting to species or regions more productive under new climate conditions, and using improved irrigation methods.
Ethiopia	Mekhonnen and Kassa, 2019	Potential adaptation strategies for farmers to cope with climate change include: diversifying crops, using improved seeds, implementing efficient grain storage practices, adjusting planting times to match shifting rainfall patterns, and reforestation.
South Western Uganda	Mugagga et al., 2019	Technical measures adopted by smallholder farmers to adapt to climate change include: applying fertilizers, planting adaptive crop varieties, and using better irrigation methods or water harvesting technologies. Agronomic adaptive measures include: early planting, mulching and terracing, contour ploughing, fallowing, shifting cultivation, using compost manure, intercropping, and crop rotation. Off-farm adaptive measures include: migration, borrowing, and taking up off-farm employment.

Genetic improvement of crop and germplasm movement are the key options for climate change adaptation of agriculture, though the present understanding of the genetic architecture of climate change evolution is inadequate. Based on the studies of Burke et al. (2009) on African crop climates, majority countries in the African continent will have new climates over half of their current crop space by 2050. Three quarters of the novel climate of these countries would be analogs to the current climate of at least 5 other countries, advocating international movement of germplasm as an essential adaptation strategy.

Altering or optimizing planting dates was prevalent among farmers as one of the low- cost adaptation

Table 2. Review of farmers' adaptation strategies to climate change for Asia, as reported in the literature

Country	Reference	Adaptation strategies
India	Ravishanker et al., 2013	Major adaptation measures were staggered sowing (dry paddy, castor, red gram and cotton in Kharif and groundnut, paddy, chilli and tobacco in rabi).Other strategies include changing planting dates, planting different crops, cultivating drought-resistant varieties, and building water harvesting structures.
Bangladesh	Ahmed et al., 2014	• Development of integrated prawn- shrimp culture with salt-tolerant rice varieties. • Translocation of prawn- fish- rice farming from coastal to inland areas
India	Banerjee et al., 2014	The wet-season rice should be transplanted during June first week, which is earlier than usual. Eighteen days aged seedlings are preferred. Mustard should be sown during November first week. If it is sown in October, the seed rate should be increased from 6 to 8 Kg/ ha.
Bangladesh	Uddin et al., 2014	• Adaptation strategies include: increased use of irrigation, diversifying crops, using drought/salinity-tolerant varieties and crop rotation/intercropping, Integrated Farming Systems (IFS), cultivating short-duration crops, seeking off-farm employment, diversifying income through non-farm activities, practicing agroforestry, implementing soil conservation techniques, implementing zero tillage, and buying crop insurance.
India	Udmale et al., 2014	• Ridge farming tillage • No-tillage • Stubble mulch farming tillage • Cultivation of less water-intensive and drought-tolerant crops • Intercropping.
Nepal	Sujakhu et al., 2015	Wage labor and migration were popular adaptation strategies among poor households. Farmers started using more chemical fertilizers and pesticides to increase yield due to a shift in the winter precipitation.
Bangladesh	Alam et al., 2017	Non-agricultural adaptation practices mainly adopted by small farmers and landless agricultural labourers include: migration, taking up off-farm work, and running petty businesses. Medium and large farmers mainly adapt by adjusting their agricultural practices, such as cultivating high-yielding varieties of rice, shifting planting times, growing vegetables and pulses, raising poultry and livestock.
Myanmar and Cambodia	Shrestha et al., 2018	• Crop diversification • Changed crops from paddy to cassava, palm fruit, sugarcane, mangoes, watermelons and vegetables. • Change in cropping calendar and crop varieties, • Increased usage of farm machinery • Shifting the location of cultivation. Farmers had formed cooperatives to implement these adaptation measures as they were unaffordable to carry out at the individual level.
Nepal	Adhikari et al., 2019	Plantation crops were preferred when farmers perceived abnormal increase in temperature. The corresponding adaptation measure for unpredictable rainfall and increased dryness of land was planting more fruit trees.
Pakistan	Akhtar et al., 2019	Popular adaptive measures were, • Cultivation of recommended varieties, • Applying more industrial pesticides, Practicing crop diversification, • Increased use of irrigation • Integrated farming system

strategies. A study conducted in Kurunegala district of Srilanka showed that when the dry season rice was planted in advance by a month, its seasonal average yield was improved compared to the base yield (Dharmarathna et al. 2014). In a study held in maize fields of Burkino Faso, it is found that decreased maize yields and crop water stress due to regional climate projections had been alleviated by optimized planting dates (Waongo et al. 2015). Based on the study of Hu et al. (2017), rainfed potato cultivation in semi-arid regions of China was improved by adjusting the sowing date, where farming was restricted by limited precipitation. The practice of altering the planting dates is a proven

Table 3. Review of farmers' adaptation strategies to climate change for Europe, as reported in the literature

Country/Continent	Reference	Adaptation strategies
Europe	Iglesias et al., 2012	The study suggested enhanced water use efficiency as a critical response to European agricultural climate risk and the need for effective extension service.
Europe	Donatelli et al., 2015	Adaptation measures such as changing sowing dates and using different varieties (in terms of duration of crop cycle) were effective in alleviating the adverse effects of climate change in most areas. However, the response to best adaptation differed across crops.

Table 4. Review of farmers' adaptation strategies to climate change in North America, as reported in the literature

Country/Province	Reference	Adaptation strategies
Canada	Wall and Smit 2005	Sustainable agriculture practices adopted by Canadian prairie producers were, • Crop and enterprise diversification • Land and water management • Livestock management • Income stabilization and crop insurance programs, Sustainable land resource management, Conservation tillage and shelterbelts for preventing soil erosion from extreme moisture deficits and high winds.
United States	Schattman et al., 2016	Popular adaptation strategies were,carefully selecting locations that minimize ecological risks, generating off-farm income to offset financial losses, and implementing Community Supported Agriculture (CSA) schemes in which farmers and members share the risk of crop failure and provide financial support to farms.
Central America	Bouroncle et al., 2017	In countries such as Guatemala, El Salvador, Honduras, and Nicaragua, there has been an increase in the average climatic suitability of crops such as Gramineae and roots, while other crops like trees and beans have decreased in suitability. Transformational adaptation strategies include restoring degraded lands, rearranging land use, livelihood diversification, and migration. Small- and medium-scale agricultural enterprises have adopted incremental and systemic adaptation strategies, such as crop and income diversification, changing planting dates, water harvesting, and introducing drought-resistant crops.

Table 5. Review of farmers' adaptation strategies to climate change for Oceania, as reported in the literature

Country	Reference	Adaptation strategies
Australia	Luo et al., 2009	The study found that the Wheat grain yield cannot be maintained at the current production level by changing the nitrogen application rate or wheat cultivar. Instead, the study found early sowing of the crop as an adaptive strategy when there was sufficient soil moisture condition in the early stages of crop growth.
New Zealand	Niles et al., 2016	The study stated that the intention to adopt adaptation practices was not associated with actual adoption of adaptation practices.

*Table 6.*Review of farmers' adaptation strategies to climate change in South America, as reported in the literature

Country	Reference	Adaptation strategies
Brazil	Burney et al., 2014	A study on climate change adaptation strategies for smallholder farmers in the semi-arid regions of Brazil revealed that interventions focused on balanced animal diets and efficient irrigation systems can help reduce the impact of climate change on the production system.
Brazil	Martins et al., 2018	The study recommended the use of improved genotypes as a potential adaptation practice. Double aptitude clones with the characteristic of tolerance to water stress and responsiveness to soil moisture were cultivated.

technique for increasing yields of grain and other staple crops. The production risks due to climate change can be minimized to an extent by adopting soil and water conservation technologies. The impact of SWC technologies as an adaptation strategy has been highlighted in many studies. Kato et al. (2011) argued that soil bunds would be appropriate strategies to adapt to climate risk in low rainfall areas of nail basins of Ethiopia, whereas in high rainfall areas, soil or stone bunds, strips of grass

and contours appear to be promising adaptation strategies.

Irrigation had been widely used as an adaptation strategy, though its effectiveness as a response measure was dubious. In the maize fields of South Africa, the effect of mid season drought or week long rain breaks was reduced by supplemental irrigation along with light rainfall throughout the season (Ndhleve et al. 2017). Whereas, the economic benefits of irrigation as an adaptation strategy in the swiss maize field was appeared to be rather small, though it led to higher and consistent maize yield (Finger et al. 2011).

Many small farmers and landless agricultural labourers preferred to do the migration, off farm work and petty business as a tackling strategy. As illustrated by IPCC (2007) report, the impacts of anthropogenic climate change had some potential effect on the global migration pattern. More frequent events of drought and floods and its impacts on crop production and productivity increased rural-urban migration in lower latitudes and dry tropical areas. As per the studies of Feng et al. (2010) on the correlation between climate driven productivity changes in the agricultural sector and out migration in Mexico, when the crop yield was reduced by 10 per cent, emigration was increased by an additional 2 per cent. It is estimated that, climate change induced emigration of 1.4 to 6.7 million adult Mexicans could happen by the year 2080 as an aftermath of declining agricultural productivity alone, depending on the warming environmental scenarios used and adaptation levels assumed, with other factors held constant (Feng et al. 2010).

The impacts of climate change can be curbed by effective land, pest and nutrient management decisions. Based on the studies of Brooks et al. (2010), when the practice of conventional tillage system replaced with minimum tillage and perennial grass, there had been a decline in the sediment loads in the paradise creek watershed over the last 28 years. Many of the pest and nutrient management decisions of farmers in the context of erratic climate events were found to be more maladaptive. The application of larger quantities of pesticides and fertilizers in anticipation of increased yield had resulted in an accelerated rate of climate change. As quoted by IPCC (2006) report, agricultural system could act as a major source of N_2O, a potent Green House Gas. N inputs used in the cropland soils contribute to increased N losses through atmospheric, surface and/or leaching pathways. Along with this, the indirect emission of N_2O is accelerated through NO_3 leaching and NH_3 volatilization. The substratum of N fertilizer best management practices is the precise use of it (Snyder et al. 2007). The soil retention and plant recovery of N fertilizers can be improved through the use of nitrification inhibitors and controlled release fertilizers, which in turn found effective in minimizing emission of N_2O.

Insurance is widely and effectively used as one of the tools for adapting to climate change. Market base for insurance premiums could act as a clear indicator of the underlying risk of natural disasters and aid farmers, governments and other stakeholders better estimate the economic impact of such events. Farmers could receive wrong economic incentives and impede adaptation strategies, if there was any premium subsidy programme in action that distorts the risk based premium (Nnadi et al. 2013).

Changing crop type is a long- term adaptation strategy. Tessema et al. (2019) had established in their study that crop switching, as an adaptation strategy, was found more prevalent in drier and hotter agroecologies of the Semienshewa zone of Ethiopia. The study revealed that crop switching is significantly correlated with the land size and agroecology. Though the changing crop type was mainly attributed to price fluctuations, it was expected to reduce the harmful effects of climate change in agriculture. (Refer Table 7)

Climate change poses significant challenges to agriculture, making it one of the most vulnerable

Table 7. Classification of adaptation strategies

Short- term	Long- term
Crop and livestock diversification	Changing crop type and location
Altering or optimizing planting dates	Development of new technologies
Land pest and nutrient management	Modernization of farm
Insurance	Improving water management
Temporary migration	Permanent migration of labour

sectors. Conventional agricultural practices and policies alone may not be enough to address the impacts of changing climate conditions. To ensure food security for a growing global population, it is crucial for countries to develop and implement climate change adaptation strategies for agriculture, particularly in developing countries where the sector is already under stress from economic and ecological factors. The impact of climate change on agriculture can vary greatly depending on location, with some regions benefiting from mild changes while others are negatively impacted. As agriculture is a vital part of rural livelihoods, failure to adapt to climate change can lead to increased poverty in rural areas of developing countries.

Studies have been conducted worldwide to identify effective response measures that can reduce the vulnerability of the agriculture sector to the impacts of climate change. These impacts can include both short-term and long-term vulnerabilities. This paper has examined popular adaptation strategies and their suitability as effective response measures. Most of the farm-level response measures discussed can be categorized as short-term adaptation strategies. These include crop and livestock diversification, adjusting planting dates, managing land, pests, and nutrients, using insurance and temporary migration. These strategies were found to be effective in managing the short-term vulnerabilities of climate variability when implemented with scientific precision. However, there is a risk of maladaptation, particularly with pest and nutrient management strategies. While short-term strategies are effective in managing the impacts of climate variability, they are insufficient for addressing the long-term threats of climate change. Long-term adaptation strategies include changing crop type and location, modernizing farms, using new technologies, improving water management practices, and permanent labor migration. Formulating long-term strategies is challenging, as the effects of climate change on agriculture are highly uncertain, which makes it difficult to predict future conditions and design appropriate adaptation measures. Secondly, Long-term climate change adaptation measures tend to require significant investments, such as in new technologies or infrastructure, which may not be feasible for many farmers. Thirdly, Long-term adaptation measures often require complex changes to farming systems, such as changes to crop types or locations, which can be challenging to implement. Fourthly, Long-term adaptation measures also require long term planning and research which can be expensive and time-consuming, and may require assistance from national or international policies. Long-term adaptation measures require political and social will that spans multiple electoral cycles and governments. Decision-makers are often motivated by short-term gains instead of long-term benefits for future generations. In summary, the unpredictability of future climate conditions, financial and technical feasibility of long-term measures, complexity in adapting, and the need for long-term planning and research, makes it more practical and viable to adopt short-term climate change adaptation measures. However, it is important to keep an eye on long-term changes in climatic patterns and remain vigilant about what is happening, in order to stay prepared for future events and also to adapt to long-term changes if necessary.

A single solution to a varying range of climate change issues is nearly impossible. Climate change adaptation involves not only individual actions but

also requires government policies to be re-evaluated and adapted to consider the impacts of climate change. As the impacts of climate change vary depending on location, sustainable development policies must take into account this diversity and be tailored to address the specific challenges of each region.

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