International Journal of Environmental Protection and Policy
2021; 9(4): 69-76
http://www.sciencepublishinggroup.com/j/ijepp
doi: 10.11648/j.ijepp.20210904.11
ISSN: 2330-7528 (Print); ISSN: 2330-7536 (Online)

Review Article

Geospatial Techniques Contribution for Climate Change Adaptation: Review of Literatures on Ethiopia

Demissie Tsega Mallie[1, 2, *], Solomon Tekalegn[1]

[1]School of Geography and Environmental Studies, Haramaya University, Haramaya, Ethiopia

[2]Department of Geography and Environmental Studies, Jimma University, Jimma, Ethiopia

Email address:
tsdemissie@gmail.com (D. T. Mallie)
[*]Corresponding author

To cite this article:
Demissie Tsega Mallie, Solomon Tekalegn. Geospatial Techniques Contribution for Climate Change Adaptation: Review of Literatures on Ethiopia. *International Journal of Environmental Protection and Policy*. Vol. 9, No. 4, 2021, pp. 69-76. doi: 10.11648/j.ijepp.20210904.11

Received: July 3, 2021; **Accepted**: July 16, 2021; **Published**: July 23, 2021

Abstract: Ethiopia is highly susceptible to the global climate change due to its fragile environment and nature of its economic base. To this effect, climate change adaptation strengthened by geospatial technologies is vital. This paper is, therefore, intended to assess the role of geospatial techniques in climate change adaptation activities. Various research articles, reports and books were reviewed. The surveyed literatures showed that geospatial techniques can help climate change adaptation either by identifying potential capabilities or estimating upcoming risks. When socio-economic and ecological vulnerabilities are assessed, it enables to alarm for the necessity of climate change adaptation, and when socio-economic capacity and natural resources endowment are clearly identified and mapped it augments climate change adaptation. That is, geospatial techniques have been utilized in various areas in order to generate geographic, climatic, geologic, biological and geo-referenced socio-economic situations of different parts of Ethiopia. In addition, there have been increased numbers of researches conducted using geospatial analysis methods that obtained opportunities from the advancement and suitability of the field. To conclude, integration of geospatial techniques enables to move toward solution of climate change problem which is geographical in its nature. Thus, all stakeholders should contribute for advancement of spatial science and have to develop the habit of applying the findings obtained from researches conducted using geospatial techniques.

Keywords: Climate Change, Climate Change Adaptation, Ethiopia, Geospatial Techniques

1. Introduction

Climate change is one of humankind's most pressing integrated economic, social and environmental issues [1]. The negative impacts of climate will be felt by all countries, and most severely in least developed countries, small Island developing states, and areas with fragile ecosystem such as dry lands, mountains and coastal areas [2, 3]. To limit damages of climate change, actions like mitigation and adaptation need to be implemented [4]. While climate change mitigation is intended to enact measures to limit extent of climate change [3], adaptation to climate change moderates harm through adjustment of natural or human systems in response to actual or expected climatic stimuli or its effects [5, 6].

The conceptualization of time-space assists in showing how climate change adaptation plans are experienced locally, and understood in relation to place that bounds climate change adaptations by shared temporal and spatial experiences show up in measurements and orientation of time and space [7]. Accordingly, adaptation varies across geographical scales (local, national, regional, global), temporal scales (coping with current versus preparing for long term) and must be addressed in complex and uncertain circumstances [1, 6].

Climate change is a geographic problem that seeks a geographic solution [8]. To this effect, there is a need for spatially explicit information on socio-economic drivers and impacts. Understanding such vulnerabilities (spatial drivers and impacts) is hampered by the availability of harmonized and reliable data of human, environmental and economic losses, and the exact delineation of area exposed to damaging intensities of the hazards [9]. In new generation research, adaptation is addressed by taking a bottom up or vulnerability driven approach, and involves assessing past and current climate vulnerability, existing coping strategies and how these might be modified with climate change [1].

Henceforth, a growing number of people with diverse objectives, backgrounds and skills require climate related information that is useful to do their work be it research, consultancy, policy, development or practice [10]. As a result, access to climate information can be a major driver of the decisions to adopt the adaptation practices [11-15]. This shows that data provide the basis for a reliable scientific understanding and knowledge, and the foundation for services that required taking informed decisions [16]. Presently, there is an increasing need for translating the massive amount of climate data and information that already exists into customized tools, products and services to monitor the range of climate change impacts and their evolution. In order to avoid a dramatic disruption of society due to climate change, it is imperative that geospatial technology is in place to manage and minimize the many inevitable impacts [17].

Ethiopia, located in the horn Africa between 3° North to 15° North and 33° South to 45° South, is characterized by fragile environment, and least developed climate sensitive and predominantly agrarian economy. In spite of its so little contribution to the cause of the problem and least capacity to deal with, the threat of changing climate and its consequences are already happening in Ethiopia [18]. For instance, it is witnessed that there are increase in temperature, decrease in rainfall and shorten drought occurrence [19-22].

Moreover, sectors like agriculture, water and health become the most vulnerable [23]. This is mainly due to, climate change in the form droughts, floods and hailstorms have been causing serious damage to life, property and natural resources which affects lives and livelihoods, and the economy of the country [24]. Gebreegziabher et al. [25] specified the need for adaptation to proceed future development of Ethiopia since the effect of overall climate change will be worsen after 2030’s. To this effect, adaptation practices greatly reduce vulnerability to climate change and variability by making rural communities better able to adjust to the changing climate [20]. But, Esayas et al. [26] argued that to offer valuable information, and planning and implementing local level adaptations; among others importance of an understanding of the temperature and rainfall variability trends and changes in the climate among agro-ecological settings. For such activities, geospatial techniques provide multifaceted options. Though its origin goes back to 1960’s [27], tremendous developments have been going with this few decades and used in various areas. Hence, this paper reviews the contribution of geospatial technologies in Ethiopia to enhance climate change adaptation strategies.

2. Materials and Methods

Articles, reports and books written in the areas of climate change were systematically reviewed. Particularly, to present the contribution of geospatial technologies toward climate change adaptation in Ethiopia studies conducted using Geographic Information System (GIS), Remote Sensing (RS), Global Position System (GPS) and related technologies were critically evaluated and thoroughly stated how they are relevant for adaptation to climate change. In the course of review, articles were downloaded from reputable and indexed publishers such as Elsevier ltd., Springer, MDPI, Hindawi, Cambrigde university press, Sage and others.

Geospatial techniques provide powerful tools for decision making related to climate change adaptation allowing us to measure, model and monitor, manage and mitigate its impacts. In order to avoid a dramatic disruption of society due to climate change, it is imperative that geospatial technology is in place to manage and minimize many inevitable impacts [17]. Adaptation planning involves full spectrum of activities from identifying and assessing to implement adaptation measures, and is informed by the assessment of impacts and vulnerability [28].

Table 1. *Researches used geospatial techniques in Ethiopia and useful for climate change adaptation.*

No.	Issues addressed	Scale of Coverage	Authors
1.	Temperature & rainfall variability & trend; climate change vulnerability	Basin; City	[29-31]
2.	Drought and its impact assessment	National	[22, 32]
3.	Malaria hotspot; risk	District	[33, 34]
4.	Land suitability for crops (rice, wheat, barley, sorghum, *teff*, finger millet); farmland; rangeland	District; Watershed; Basin	[35-42]
5.	Ground water potential	Basin	[43-46]
6.	Surface irrigation potential	Watershed; District	[47-49]
7.	Water balance	Landscape	[50]
8.	Green space development	City	[51, 52]
9.	Ecotourism suitability	Landscape; District	[53-56]
10.	Land use land cover (LULC)	Watershed; Basin; District; Landscape	[57-76]

3. Geospatial Techniques and Climate Change Adaptation

Smit and Wandel [77] summarized the purpose of climate change adaptation under four categories. Firstly, it estimates of the degree to which modeled impacts of climate change scenarios could be moderated or offset by adaptation to impacts. Secondly, it assesses the relative merit or alternative adaptation to identify best or better one. Thirdly, it provides an evaluation of relative vulnerability (and/or relative adaptive capacity) of countries or regions usually using some kind of indicator, scoring, rating or ranking procedures. Lastly, it contributes to practical adaptation initiatives by documenting the ways in which a system or community experiences changing conditions and the processes of decisions making in this system that may accommodate adaptation or provide means of improving adaptive capacity.

Though the role of geospatial techniques can be placed in all areas, more relevance and contribution can be provided to the last two purposes of climate change adaptation research suggested by Smit and Wandel [77]. That is, from their vast reservoir of knowledge, expertise and practices, GIS users can apply in the science of climate change and understand its impacts on both human and natural systems [8]. So, geospatial techniques can be used to alarm adaptation through investigating vulnerable human and environmental aspects, and augment the adaptation by bringing right decisions at right places and situations that probably boost coping ability of environment and society (Figure 1). Therefore, papers were evaluated based on relevance to identify vulnerability and enhance adaptive capacity.

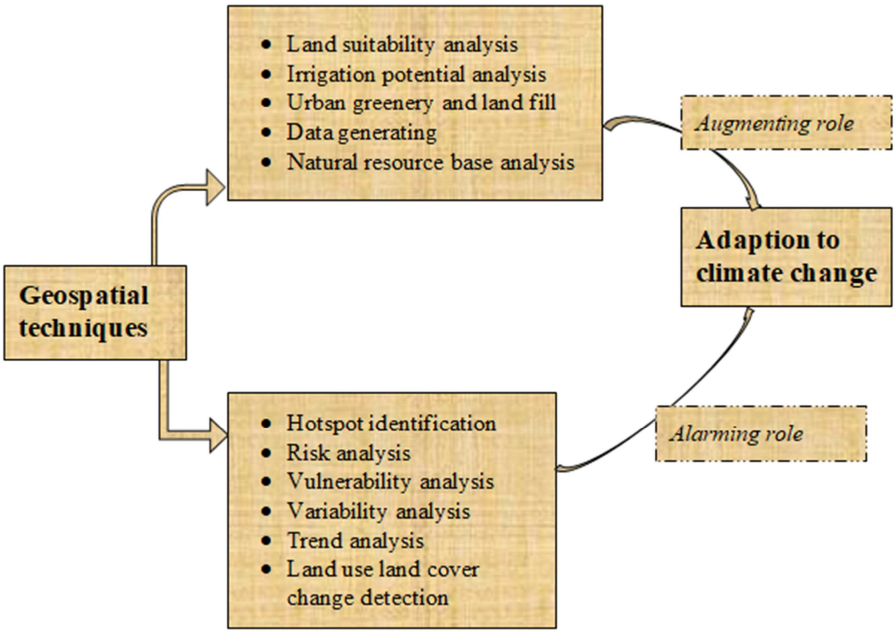

Figure 1. *Links of geospatial techniques to climate change adaptation.*

3.1. Alarming Climate Change Adaptation

Adaptations to climate change include initiatives and measures to reduce the vulnerability [78]. According to Smit and Wander [77], vulnerability taken as the starting point rather than the residual or end point and assumed to be measurable based on attributes or determinants selected a priori. Vulnerability mapping, therefore, helps to target vulnerable hotspots; assists decision makers in recommending existing adaptation measures and prioritizing resource allocation to specific areas; and determine investment for adaptation measures for future impacts of climate change [79]. In this regard, studies have been conducted in different parts of Ethiopia using geospatial techniques to investigate vulnerability issues [22, 29-34].

In order to analyze the spatio-temporal variability and trends of rainfall and temperature over upper Blue Nile basin of Ethiopia, Mengistu et al. [29] used rainfall data of Meteosat and temperature data of NOAA (MODIS) reconstructed by Ethiopian National Meteorological agency in collaboration with International Research Institute for Climate and Society at Colombia university, USA, and trend maps were generated using geostatistical techniques based on the input point data to GIS environment. Arnold et al. [30] argued that improved rural accessibility is vital to reduce the number of highly vulnerable communities and increases rural resilience. So, they have utilized geospatial indicator-based risk and vulnerability assessment method for determining rural access roads that are highly vulnerable to changing climate in Ethiopia. Feyissa et al. [31], also, used GIS for quantification and mapping of climate change vulnerability hotspots in Addis Ababa.

Drought is a slow-onset natural disaster that causes in evitable damage to water resources and to farm life. So that, to enhance the farmers' ability to cope with drought, assessment of drought can be used as a benchmark [80]. In this regard, Suryabhagavan [32] analyzed climate variability and drought frequency of potential crop growing regions of Ethiopia during 1983 to 2012 using spatial interpolation techniques. Moreover, Liou and Mulualem [22] used pixel-based Mann-Kendall trend analysis and vegetation condition index to assess drought and its impacts in central highlands and northwestern part of Ethiopia by using processed 18 years (2001-2018) of Moderate Resolution Imaging Spectro-radiometer (MODIS) terra/aqua, Normalized Difference Vegetation Index (NDVI), Land Surface Temperature (LST), CHIRPS daily precipitation and FEWS NET land data assimilation soil moisture datasets.

Since about 75% of Ethiopia's landscape is favoring the breeding of malaria vector, it is important to assess risk not to be further aggravated in the changing climate and compromise the adaptive capacity. For this reason, geospatial tools have a significant role in malaria risk assessment [32-34]. Eniyew [34] focused on mapping malaria risk areas of Fogera plains of northwestern highlands of Ethiopia by integrating GIS and remote sensing. Similarly, Dessalegne et al. [33] identified four categories of malaria risk in Mecha district of west Gojjam using geospatial techniques.

East African landscapes are the results of the cumulative effects of climate and land use changes over millennial timescales. Results from archaeological and palaeo-environmental data showed that throughout east Africa there have been a series of relatively rapid and high magnitude environmental shifts manifested as a marked change in rainfall amount or seasonality and subsequent hydrological changing [81]. Land use modification induces influence up on climate [68, 82]. And also, LULC change affects the timing of rainy season, lake retreat and drought outbreak [60]. In Ethiopia, various studies intended to assess drivers of LULC change [59, 72]; analyze LULC change [57, 58, 61, 63, 66-68, 74, 76]; assess LULC change impacts on various environmental parameters [61, 62, 64, 65, 69, 75, 83]; and prediction of future LULC change [57, 70] were conducted using geospatial techniques. Thus, the findings of these studies can be used as an input for designing adaptation strategies of changing climate impacts in the country. This is mainly because, Smit and Wandel [77] suggested as adaptation efforts should be directed to those areas with greatest exposures or least adaptive capacity.

3.2. Augmentation of Climate Change Adaptation

Not alone from vulnerability context, adaptation of human activities to climate change is also considered in the context of adaptive capacity [77]. In order to understand adaptive capacity of a given society and environment, an investigation of resource base of a given nation is significant. Otherwise, due to mismanagement and intensive cultivation, land becomes less productive [42]. That is, mismatch between the actual requirements and what is actually implemented in a given land could be avoided through land suitability evaluation by identifying the inherent land potential and constraints [41]. To this effect, land evaluation is a foundation for sustainable land resource planning and management [42].

In Ethiopia, geospatial techniques have been used for identification of agricultural potential areas [39]. More specifically, various studies on crop production suitability analysis [35-38, 40-42, 84] were conducted and identified localities appropriate for better production. Moreover, researches were also conducted to assess surface irrigation potential and suitability [47-49], and evaluation of water balance components of potential agriculture [50] was also done.

Similarly, ground water potential assessment was also conducted [43, 44, 45, 85-86]. For urban greenery planning and practice, there were also implementation of GIS & RS techniques [51, 52]. In order to preserve ecology and sustain its economic and scenic values, eco-tourism sites were identified using geospatial techniques [53, 54, 56]. In general, the use of geospatial techniques in identification of agriculture suitable areas, conducive land for surface irrigation, ground water potential, urban green development and ecological friendly human activities potential areas were boosting climate change adaptation options and strategies.

4. Conclusion

Climate change is a geographic problem that seeks geographic solutions. So that, integration of geospatial tools for understanding problem climate change in general, climate change adaptations in particular, provide additional methods. These tools can help climate change adaptation through assessing the possible anthropogenic and natural expletives, and socio-economic and ecological blessings extent and set up for both for preparedness and endowments not to be disturbed by impacts of climate change. Regardless of its more necessity for further improvement, many researches that contribute for climate change adaptation have been conducted using geospatial techniques. These tools were used for data generation and/or analysis.

Based on information of materials reviewed in this paper, the contribution of geospatial techniques in climate change adaptation can be viewed by two perspectives. Firstly, these techniques were utilized to assess socio-economic and ecological vulnerabilities. In line with this, using single and combinations of geospatial techniques, there were studies conducted on spatio-temporal variability and trends of temperature and rainfall, infrastructure (e.g. roads) accessibility, climate change hotspot areas, drought frequency and impacts, disease outbreak risk (e.g. malaria risk and hotspots) and LULC changes and helps by alarming the climate change adaptations. Shortly, this is what geospatial tools help end users by letting to be primed accordingly.

Secondly, geospatial techniques can serve to enhance adaptive capacity of a given society and environment by proper potential identification and mapping. Since agriculture is the mainstay of Ethiopia's economy and its susceptibility to climate related difficulties, studies conducted on assessing arable land potential, crop production suitability, rangeland suitability, surface irrigation suitability and assessment of water balance component for agriculture using geospatial techniques provides options for decision makers and our farming communities. To overcome stresses due to water supply deficit, ground water potential can provide an option. In addition, urban green area development and eco-tourism site selection provide livelihood options and serves for burgeoning of climate change adaptation strategies.

5. The Way Forward

It is appreciable to see establishment of agency by re-endorsing Ethiopian Geospatial Information Agency Re-Establish the Proclamation Number 1079/2018. But, institutions of higher educations and newly re-organized Ethiopian Geospatial Information Agency (former Ethiopian Mapping Agency) need to create link with international institutions and donors for free availing of high resolution satellite imageries and other related data as well as licensed software that are capable of performing all commands and functions. Integration of spatial science among disciplines and practice-based delivery of courses enables to produce more researchers in the area to use this emerging technology. Above all, decision makers such as government and other stakeholders have to use the research findings to solve practical problems in their localities.

Conflict of Interest

The authors declare that they have no competing interests.

Acknowledgements

Authors really thank the publishers of all articles whom making open access.

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