The Use Of Remote Sensing In Sustainable Management Of Environment In Ethiopia

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ABSTRACT: Remote sensing (RS) helps environmental scientists in obtaining information about objects or areas at the Earth's surface by using electromagnetic radiation without being in direct contact with the object or area. It is a potential tool for environmental process modeling and to study environmental processes such as land cover changes, deforestation, vegetation dynamics, forest density, coastal morphology, agricultural crop growth, water quality dynamics, urban growth, status of reef and biodiversity of islands and etc. This paper explores the uses of RS in sustainable management of environment in Ethiopia. Several studies have been carried out on the use of RS related to sustainable management of environment and authors contribute to information generation for decision-makers, land managers and planners for sustainable development and management of the natural resource in the environment. They authors reported that land use land cover (LULC) changes and vegetation dynamics in complex landscapes in Ethiopia on a detailed spatial scale; investigated the potential of combining RS data from different Landsat sensors in the country are because of demographic pressure and associated demand on the environmental resources. Accordingly, the effects of human activities are immediate and often radical, while the natural effects take a relatively longer period and the difference in increase by households and land cover change indicates the pressure on forest and bush land. In order to make relevant natural resource planning and management, one has to properly consult situations of the past and present, i.e. socio-economic and biophysical aspects of the environment.

Keywords: Remote Sensing, Land Use Land Cover, Vegetation Dynamics, Satellite Image, rural households, Agricultural expansion, Urbanization, Ethiopia.

1. Introduction

RS also called earth observation refers to obtaining information about objects or areas at the Earth's surface by using electromagnetic radiation (light) without being in direct contact with the object or area. Increasingly, RS is used to acquire information about environmental processes such as agricultural crop growth, land cover changes, deforestation, vegetation dynamics, water quality dynamics, urban growth, etc. In recent years, remotely sensed data has been widely used for its application in various natural resource management disciplines. It is a potential tool to study change in land cover, forest density, coastal morphology, status of reef and biodiversity of islands even if, located in remote place [77]. RS is the science of obtaining information about the Earth using highflying aircraft and satellites. The data is collected by sensors attached to the aircraft that detect the energy that is reflected from Earth. Remote sensors fall into two classifications; passive and active. In response to external stimuli, passive sensors record the natural energy emitted from the Earth's surface. Reflected sunlight is the most common source of detected radiation. Active sensors differ in that they use internal stimuli to collect data. A common example is the use of a laser-beam RS system, where data is collected by projecting a laser to the Earth's surface and measuring the time it takes for it to be reflected back to the sensor [54]. RS has a wide range of applications for environmental planning and management. Coastal applications, ocean applications, hazard assessments and natural resource management are just a few of the broad areas under which fall an array of analyses such as; monitoring shoreline changes, measuring ocean temperatures, tracking the impacts of natural disasters and charting wildlife habitats. These types of analyses all aid in the effective planning and management of the land and water, and its resources [104]. According [66] traditional data collection methods such as demographic data, census and sample maps were not satisfactory for the purpose of urban land use management. Accurate information of land use and land cover change is therefore highly essential to many groups. To achieve this information, remotely sensed data can be used since it provides land cover information. The instruments used for measuring electromagnetic radiation are called sensors. These sensors record the reflected radiation from the surface of the earth and will be used for many analyses; one of these is LULC change analysis [106]. Today, RS, which can be considered as a scientific tool, is applied in almost every field of Earth and environmental science. NASA's SMAP Mission strives to achieve the benefits of both active and passive sensors by using two instruments; a radar (active) and a radiometer (passive), to determine soil moisture content. The data observed from SMAP's measurements will advance multiple disciplines of environmental management. These measurements can aid planning and management authorities in developing and implementing measures to reduce vulnerability to drought, with its predictions that can promote risk management as opposed to crisis management [64]. Numerous benchmark studies have been carried out on the role of RS in sustainable development, covering a variety of sub-topics within the fields of environmental assessment, natural hazards, and socioeconomic development, among others [40]; [17]; [58]. Similarly, In Ethiopia, Several studies were conducted [14]; [46] related to LULC changes with a variety of drivers, which include demographic pressure and associated demand on the environmental resources using RS derived data [26]. According to [92] Ethiopia is facing huge LULC change which is mostly of natural resources to the farming system and human settlement. As a result the uses of RS very important to become aware of those dynamics in the environment of the country and seemingly many researchers have been carrying out so many researches on how to sustainably manage the environment of Ethiopia . Considering the importance of sustainable development in the 21st century, this review aims to assess how RS used in sustainable management of the environment in Ethiopia. The objective of

this review is to explore the uses of RS in sustainably managing the environment of Ethiopia.

2. LITERATURE REVIEW

2.1. Remote Sensing as a Research Tool In Environment of Ethiopia

2.1.1. Remote Sensing for Land Cover Dynamics Study in Ethiopia

Before the past three decades [40] tried to construct land cover changes through vegetation composition analysis at that time. They described that tree-shrub clusters show a strong relationship with land use and some habitat characteristics, while clusters of herbs are indicators of intensities of anthropogenic pressure in the Rift Valley. They also stated that exacerbated land cover changes and wetland alterations in Abijjata-Shala area are new phenomena whose real effect on the avian populations has not yet been adequately addressed at that time. Similarly, they reported that the extent and rate of the gradual shift from pastoral to agropastoral land use practices and at the time were expansion of the sedentary agriculture system by the local inhabitants may provide important hint pertaining the spatio-temporal LULC change process. [73] reported that the decline of forests and woodlands rises in the Central Rift Valley, Ethiopia and the risk of land degradation with a knock-on effect on people that depend on them and explained that the need to focus on halting deforestation in order to stop further land expansion into forests and woodlands; development of alternative energy sources and suggested for future land management directions. Similarly, Kumsa (2015) observed that the difference in increase by households and land cover change indicates the pressure on wetland, Shrubland, grassland and forest cover and related biodiversity, and implies that population pressure, institutional factor, economic development and increase the forest and according to his observation agricultural product price is believed to be one of the major driving forces for the changes in Western Ethiopa. Very recently, Barvels et al. (2021) reported to examine vegetation dynamics in complex landscapes in Ethiopia on a detailed spatial scale; investigated the potential of combining RS data from different Landsat sensors using cloud-based geospatial processing supporting a high-resolution time series analysis which showed a shift from browning (2002–2010) to greening (2011–2018) along with an overall greening trend over the full period (2002–2018). Accordingly, from the spatiotemporal patterns of NDVI and rainfall it could be concluded that the browning trend was not explained by long-term changes in rainfall. They reported that no clear patterns of anthropogenic induced changes in vegetation were found when aggregating results at the catchment scale, as NDVI median trends did not clearly indicate better development in SLMP intervention areas than in control areas. They stated that Visual inspection based on multi-temporal Google Earth imagery showed that the changes in NDVI and rain-use efficiency did spatially overlap areas of small-scale land improvements related to human management, however, on a smaller scale than a micro-watershed (the smallest aggregation level). [73] explained that the Natural forest cover can contribution for slowing down the rapidly expanding desertification south of the Sahara desert using data derived by RS techniques. Similarly, they examined that area closures importance in increasing the bushland coverage of the region; taking particular site such as North Wollo, South Wollo, and Oromia zones as a best example from Ethiopia. [93] Stated that the Understanding the change in natural or semi-natural ecosystems induced by humans, the source of dynamism and the consequence of it on functionality and sustainability are prerequisites for protected area management at local level. The number of people and their livestock number may be counted occasionally. The Expert- Context-Edition suggested and adoptability for multitemporal analysis of land cover changes. [52] Explained that the people component score is relatively higher than institutional, data, technology and policy and the technology component of the NSDI is very poor. Moreover, [76] reported that the impact of urban expansion on the agricultural land use. He explained that considerable land use land cover change around Gondar city in Ethiopia has been taking place. Accordingly, he explained that impact being exerted on agricultural land in the area is much more than that of the other land uses. He also, examined that intensified land use transformation due to urban land use encroachment especially that of new residential development in the city. Regarding to the socio economic impacts exerted, it could be seen from two basic dimensions. The impact of urban expansion on the agricultural land is the first one because the land is the most important economic base for the rural residents. Urban expansion consumes agricultural land use farm lands become smaller and smaller. Decreasing in agricultural land holding and food production ranks at the top of the problem imposed on rural societies. [99] assessed land use and land cover change using RS techniques in Northwest Ethiopia'' and their finding revealed that the change of forest, bushland, and grassland to agricultural and residential areas which may problems including change in streamflow, soil degradation, and hydrological system in the basin which have implications for sustainable resource management and the livelihood of the local society. Also from their inspection they recommended that improved land management practices particularly, on areas like soil and water conservation, improved agricultural inputs, integrated watershed management (land use planning and management), and active participation of local community for prevention of undesirable LULC dynamics in the basin and deliver useful information for understanding of the seasonal patterns of land use dynamics for planners and decision-makers. According to [55] the habitat of hippopotamus in Lake Tana and its environs were highly reduced due to mainly human factors; much more emphasis should be placed on preserving of this vulnerable species in the area. According to [12] observation the natural environment in Finchaa valley has been modified due to agricultural and industrial developments since 1975 and following that modification the irrigation project have both positive as well as negative impacts on the environment and indicated that the natural vegetation biomass is declining mainly due to the expansion of agricultural land and escalating human made structures in the area. [31] reported that the major vegetation classes revealed a decreasing trends and increasing trends of rainfall with different significant percentage in the whole basin as well as for different major land cover types in Awash Basin area. [96] reported that woodland cover of the Borana rangelands in eastern Ethiopia is increased from 11.3% in the 1973 to 49.26% in 2003. On the other hand they confirmed the decrement in grassland cover from 58 to 32% during the same period. As consequences from their findings in above statements cultivated areas gradually increased from 2 to 5% but it is lower compared to the woodland cover

expansion rate. As their explanations the decrease of normalized difference vegetation index (NDVI) values for 2003 compared to the 1973 is also an evident for the reduction of vegetation. Severe droughts, population increase, poor government policy are among the major drivers of LULC changes in the study area. [96] presented key information on LULC changes which is vital for understanding land use dynamics and monitoring resources over time and support policy makers with information insights to make informed decision over land use planning and enhancing pastoralists' livelihoods through proper support for Borana rangelands in eastern Ethiopia. As the study from Tigray Region, Ethiopia with the help of RS revealed that the existence of significant land use and land cover changes for the last abbot 50 years. More specifically, the expansion of cropland at the expense of forest land and the land cover dynamics with a span of 50 years experienced significant rates of conversion of land cover types in the area and it is largely attributed to the expansion of crop land [107]. According to [53] the forest cover change in the form of deforestation is one of the major land resource degradation problems noticeable in Ethiopia. Additionally, [60] stated that the effects of human activities are immediate and often radical, while the natural effects take a relatively longer period and the difference in increase by households and land cover change indicates the pressure on forest and bush land. Population pressure and limited income diversity is believed to be one of the major driving forces for the change of land use land cover. In order to make relevant natural resource planning and management, one has to properly consult situations of the past and present, i.e. socio-economic and biophysical aspects of the watershed. In the same manner, [76] stated the land resources management measures practiced effectively could improving the vegetative cover, reducing soil loss, improving crop yield and becoming main source of forage for livestock. In addition, the land management measures have substantially contributed to the improvement of the livelihood of the population. In line with these, [33] stated that the environmental implications such as climate change, biodiversity loss, scarcity of basic forest products, habitat alteration, decline in quality and availability of water, and crop yield reduction are resulted from the LU/LC change and they explained that if the tendency of LU/LC change continued, it will have serious environmental and economic consequences with impact on livelihood of local people and commended the importance of appropriate measures to ensure wise use of natural resources and efficient utilization of land for the area as consequences. Similarly, Land degradation can put the sustainability of agriculture and availability of natural resources in the environment as the report from analysis of land lover change detection in Gozamin District, Ethiopia [16]. Similarly, as [5] the most commonly mentioned human activity, for natural resources degradation is agricultural expansion and improper land management. According to [27], production linkages were very weak except for the backward production linkage which was reflected mainly in the use of inputs and the forward production linkage was almost missing in the Adwa Town and its Surrounding Rural Areas since none of the households sold their agricultural produce to agro-processing plants. [16] stated that the land degradation can put the sustainability of agriculture and availability of natural resources in the Gozamin District at a great risk, leading to a decline in crop production as well as to a shortage of forage for livestock. [83] stated that the time series analysis result reflected that rainfall, minimum temperature and maximum temperature observed in the study area have shown a clear spatial and temporal variation which contributed for the present climate dynamics in the locality with considerable spatial variation of rainfall and temperature using GIS and RS techniques application. Accordingly, among the different rainfall features considered, rainfall onset, end time and duration are found to be the variable ones. [47] stated that the impotence of high-resolution satellite information, for researchers and scientists to acquire augment other satellites information that helps to monitor many Earth variables and analyze the changes attributed to crop yield, land use or land cover changes and their impact on the total climate system. It would also complement the ground measurements of geospatial and meteorological variables to the Ethiopian National Meteorological Agency (NMA), Ethiopian Geospatial Information Agency, Ethiopian Disaster Prevention and Preparedness Agency and so on. EO4SD Agriculture and Rural Development - Ethiopia [34] stated the essentiality of RS base data to support the planning of sustainable food security interventions and to track the progress and impact of investments over time. Moreover, environmental information over large areas based on satellite data will catalyse evidence based implementation the projects by providing a concrete and operational contribution to the program-level monitoring and evaluation (M&E) tools and a cost-effective system for scaling up successful initiatives. Accordingly, the services can provide independent and authoritative environmental variables that build a stronger indicator framework and indicators can demonstrate how different program investments are addressing drivers of environmental degradation and agro-ecosystem resilience, as pursued by the Sustainable Development Goals. [50] stated that the change has adverse environmental implications, which would be exacerbated if the same trend continues. In more detail they show that the urgency for a robust local level natural resource management program o mitigates the deleterious impact resulting from the degradation of natural resources. [98] reported that since 1986 the green spaces, represented by plantations, forestland, grassland and cultivated land have been transformed into other land uses at annual rates of 5.9%, 3.3%, 5.4% and 3.7 % respectively and the shrinking of plantations, forestland, grassland and cultivated land by 82.1%, 62.1%, 78.8 and 65.8 % respectively. In contrary, built-up and transport areas have been highly expanded with an annual rate of 5.7% and 1.3% and with a total area increase of 419% and 47% respectively. [103] reported that rapid expansion of urban land is directly linked with the activity of man such as population pressure dynamics (natural increasing and migration), and the socio-economic factors such as expansion of investments activities Sululta Town; Oromia Regional State of Ethiopia. Furthermore, [99] suggested that LULC change study is critical for environmental protection strategy and sustainable resource management of basins. They contribute on information generation for decision-makers, land managers and planners for sustainable development and management of the natural resource. GIS and RS could deliver useful information to understand the seasonal patterns of land use dynamics for planners and decision-makers consequently sustainable land management planning is possible.

2.1.2. Remote Sensing for Land Suitability Analysis

[23] proofed that the application of GIS and RS technique for the identification of suitable solid waste dumping site could minimize the environmental hazard and human health difficulties. Similarly, he has shown the ability of GIS and RS as a veritable tool for analyzing the criteria for decision making and has taken important issues to minimize the negative impacts of solid waste landfill site. [51] in their Assessment of suitable industrial site in Assosa Town, Ethiopia'' stated that land use and land cover factors were highly determined in the selection of industrial sites, and more explicitly elevation and slope determine minimum when compared with other factors. Additionally, [85] reported that 75.7% of Bonga Town, in Southwestern Ethiopia is unsuitable, for solid waste disposal using data assisted with help of RS techniques. Scientifically they assured that existence of problems in locating suitable sites for solid waste disposal in the area and tried to provide information to the administrators and planners of Bonga Town to locate an appropriate site for solid waste disposal and support them in resolving solid waste administration snags. Similarly, [11] reported that 45.4% of the Modjo Town in Eastern part of Ethiopia is unsuitable for solid waste dumping with only 22% the study area is suitable for solid waste disposal and recommended that south west and west part of the Mojo Town highly suitable areas for solid waste dumping sites with least environmental and health risks. [4] reported that areas only about 28 % suitable areas for tourism development with different level of Suitablity while the rest large area accounting the highest percentage about 72 % or 1001098.35 ha for not suitable areas for the purpose in East Gojjam Zone of northern Ethiopia using GIS and RS derived data. In the same manner, [28] shown the ability of GIS and RS as a genuine tool for analyzing the criteria for decision support and reporting that about 47.5% of the Hawassa Town, Ethiopia as suitable site to establish industries and a small portion only about 0.2% as a less suitable site to locate for industry using GIS and RS technologies. [44] Stated that GIS and RS techniques are widely employed towards assessing habitat potential and modeling suitable areas through evaluating multi-criteria for wildlife corridors. In general, the result from this study appears practically useful for natural resources management in Bale Mountains National Park. Especially with the availability of low cost and timely satellite images as well as recent advances in GIS and RS technology, the use of remotely sensed data for natural resource management becomes more feasible and efficient.

2.1.3. Remote Sensing for Health Risk Assessment in Ethiopia

[9] in his Paper Entitled '' Malaria Risk Assessment Using GIS and Remote Sensing: A Case of Kewet Woreda, North Shewa Zone, Amhara Region'' indicated that, 25% of the study area is in very high malaria risk, 45.4% of the area in high and the remaining 22.9% and 6.7% of the area in moderate to low malaria risk respectively due to the existence of suitable climatic condition, lower elevation, river, swamp and wetland plays a great role for the spread of malaria in the study area using RS data. Similarly, [88] shown potential roles of RS in malaria prediction and describes the state-of the-art in modeling risk of malaria transmission using remotely sensed data in their study of '' The Current and Potential Role of Satellite RS in the Campaign Against Malaria''. [18]; [94]; [43] stated that RS is a useful tool for studying the effects of environmental conditions on mosquito borne diseases like malaria. In Ethiopia, such studies have established relationships between malaria risk and remotely-sensed environmental factors, such as land surface temperature [78], [79]; [20], precipitation [79]; [24], greenness and moisture indices [78], and distance to water bodies [79].

2.1.4. Remote Sensing for Water Bodies in Ethiopia

[2] reported that climate and land surface changes impact surface water resources in Ethiopia and suggestd that hotspots mapping using large-scale geospatial and temporal Budyko framework and explained that RS data can be effectively used to gain deeper understanding of the hydrological cycles, water resource dynamics and to assess the contribution of climate variabilities and change, as well as the role of land surface and land-cover changes on water resources in a geographically and agro-ecologically diverse Sub-Sharan countries and landscapes such as the one in Ethiopia. Similarly, [29] reported that the groundwater recharge and potential assessment, the infiltration and percolation capacity is assessed in terms of the clay fraction, which is presumed to be the major attribute that influences soil permeability. The importance of sediment deposition in the stream and on its banks is related to land degradation in the upper catchment, and to artificial rising of Lake Tana level that creates a backwater effect and sediment deposition in Gumara River and showed that the considered reaches of the river have undergone little changes to the position of the meanders. Accordingly, the comparison of cross-sections through time illustrates that the vertical morphological changing process is very active and anthropogenic activities along the banks of the river have facilitated bed deposition. The raise of the river bed level amplifies the flashy nature of the river, and as a result more frequent high floods and sediment concentrations may occur [1].

2.1.5. Remote Sensing as an Alarming Tool for Resources Conservation in Ethiopa

[91] stated that most intact high forests concentrate within the boundaries of 'National Forest Priority Areas'. The ongoing deforestation is a result of the very high human pressure on the natural resources, and gives alertness for the concerned Environmental sectors of Ethiopia. Similarly, [32] using RS data indicated that the need for immediate adoption of conservation strategies in areas with high and very high erosion risk to prevent further land degradation. Correspondingly, [101] stated that rapid population growth demanded more land for cultivation, more trees for domestic fuelwood consumption and more area for settlement had been responsible for drastic change in the land use/land cover change in the last 3 decades in the Beressa watershed. In order to check the loss of area from gazing land and barren land, alternative source income opportunities to the community dwellers may be provided. Environmental conservation, management and rehabilitation require integrated approach of community development at various levels. [15] reported that estimated soil loss was found to be different in different land use/land cover type and slope gradients and the land use/land cover map and recommended that soil loss hazard map as an inputs for decision-making support system for sustainable land use planning and land management. Moreover, [102] provides a new set of information for understanding complex spatial

distribution of cover types and interactions of human influence in terms of land use reported that the Loss of significant riparian and forestlands within the study area using remotely sensed data. In their study of Integration of RS and Geographic Information System Technology for Monitoring Changes in the Northwestern Blue Nile Region of Ethiopia, [13] reported that commercial fishing combined with declining livelihoods could be an important driver of settlement concentration in the upper Delta of Omo, Ethiopian using RS data. It seems that because of all the above reasons National REDD+ Secretariat (2015) is reported that it is on the way for implementation'' for preparatory activities to develop sound MRV system with combination of ground based actual forest inventory using RS techniques.

2.2. Discussions

In all cases authors of the explored research papers shown the uses of RS in providing data and assisting the efforts researchers have been exerting assessing the environmental recourses statuses. In doing so they had clearly indicated that the usefulness of RS in sustainably managing the environment of Ethiopia. Moreover, in seeing particularly, many research papers that have been reviewed in this paper are those have been dealt on LULC dynamics and reported that the declining stage of environmental resources of Ethiopia and call for urgent need for remediation of the trends of the diminishing natural resources of the environment. The authors' findings and Understanding on the change in natural or semi-natural ecosystems induced by humans, the source of dynamism and the consequence of it on functionality and sustainability are prerequisites for protected area management at local level. However, there is significant number of papers those dealt with Malaria Risks to society and its distributions aspects particularly. Additionally, there were papers explored for dealing on water and related issues like sediment deposition in the environment. Many of the studies conducted on the uses of RS in environmental management sustainability aspects in Ethiopia are reported that all most all drives for currently diminishing environmental recourses are of demographic pressure and associated demand on the environmental resources for livelihood sustenance. Studies undertaken on assessments of urban environment suitability for different uses have come some important works that might simplify the works of municipality in areas like urban land allocation for different purposes based information provided with these RS data users' researchers. However it needs to proof the results from research reports with actual ground resources. In most cases authors have been attempted to generate and provide more clear information for decision-makers, land managers and planners for intervention on sustainable development and management of the natural resource.

2.3. Conclusions and Recommendations

RS refers to obtaining information about objects or areas at the Earth's surface by using electromagnetic radiation without being in direct contact with the object or area. It has a wide range of applications for environmental planning and management and is increasingly, being used to acquire information about environmental processes such as agricultural crop growth, land cover changes, deforestation, vegetation dynamics, water quality dynamics, urban growth, etc. and thereby helping to manage environment sustainably. To achieve this information, remotely sensed data are crucial for a well-informed decision-making regarding proper sustainable environmental management. In Ethiopia on a detailed spatial scale; investigated the potential of combining RS data from different Landsat sensors using cloud-based geospatial processing supporting a high-resolution time series analysis which showed dynamism in its environment and the consequence on environmental productivity and sustainability are prerequisites for sustainable management environment. Problems of land use and land cover change like the change in forest, bushland, and grassland to agricultural and residential areas which are currently prevailing in the country could be addressed with wisely utilization of information generated by the use of RS. Moreover, to increase the RS derived information use for sustainable environmental management, it is better to link information flow between concerned stakeholders' i.e. environmental decision makers and RS base produced information sources.

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