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Modification and Climate Change Analysis of surrounding Environment using Remote Sensing and Geographical Information System

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Abstract: *This review is presented in three parts. The first part explains such terms as climate, climate change, climate change adaptation, remote sensing (RS) and geographical information systems (GIS). The second part highlights some areas where RS and GIS are applicable in climate change analysis and adaptation. Issues considered are snow/glacier monitoring, land cover monitoring, carbon trace/accounting, atmospheric dynamics, terrestrial temperature monitoring, biodiversity conservation, ocean and coast monitoring, erosion monitoring and control, agriculture, flood monitoring, health and disease, drought and desertification. The third part concludes from all illustrated instances that climate change problems will be less understood and managed without the application of RS and GIS. While humanity is still being plagued by climate change effects, RS and GIS play a crucial role in its management for continued human survival. Key words: Climate, Climate Change, Climate Change Adaptation, Geographical Information System and Remote Sensing.*
Keywords: *Biometrics, Multimodal, Multi-algorithm, Techniques, fusion*

I. Introduction

1.2.1 Explanation of basic terms

A critical and perhaps the dominant global environmental problem in the last three decades is global warming, resulting from global climate change (Scholz and Hasse, 2008). Global Warming is an increase in Earth's average surface temperature, due mostly to the release of greenhouse gases (GHGs) such as carbon dioxide (CO2), methane (CH4), water vapour, Nitrous oxide NO2, chloro-floro-carbons (CFCs), among others into the atmosphere by human-fuelled activities such as increased fossil fuel consumption (Benson, 2008).Climate is the long-term weather pattern (for at least 30 years) in an area, including general patterns and extremes of drought, rains, storms, and freezing temperatures (Waskey, 2008). Climate change is the long-term change in global weather patterns, associated especially with increases in temperature, precipitation, and storm activity (Benson, 2008).Climate change is a direct consequence of the continued increase in the atmospheric CO2 mainly resulting from the anthropogenic emissions from fossil fuel burning (Cox et al., 2000; Post et al., 2004; Lehmann, 2007; Scholz and Hasse, 2008; Sheikh et al., 2011).

The concentration of CO2 in the atmosphere is said to be accelerating at an annual rate of 1.91 parts per million (ppm) (Sheikh et al., 2011). CO2 has increased in volume by 30% since the industrial revolution and its tripling is expected at the end of the 21st century (Post et al., 2004).During the last century, it has also increased from 280 ppm to 367 ppm (Ordonez et al., 2008). The continued large-scale CO2 emission can produce adverse environmental, economic, social, health, agricultural impacts on humanity (Kassas, 1995; Caldeira and Rau, 2000; Sheikh et al., 2011; Schilling et al., 2012) at local, regional and global scales (Sheikh et al., 2011).

Climate change manifests itself in different spatio-temporal dimensions and scales (Pittock, 2009). Schilling et al. (2012) notice that negative precipitation, tendency towards warmer and drier conditions and increase in the likelihood of drought risk would cause environmental degradation, decreased agricultural productivity and consequent endangerment of food security and economic and societal instability particularly in the Northern part of Africa.

Climate change can result in significant land use change and land cover shift (Briner et al., 2012), aggravate drought (Kassas, 1995) and modify the capacity of the ecosystem to provide ecosystem goods and services (Briner et al., 2012). The effects of climate change range from ―shifts in ice freeze and break-up dates on rivers and lakes; increases in rainfall and rainfall intensity in some areas with reversal in other areas; lengthening of growing seasons; and precipitation of flowering of trees, emergence of insects, and egg-laying in birds‖ (Pittock, 2009). The eventuality of these is that human survival is threatened

The climatic conditions on the Earth have ever been and will ever be changing. Amid the dire warming of severe weather perturbations and global warming, scientists and policy makers have been searching for ways of tackling the menacing threat of climate change (Herzog, 2001). For geo-scientists, understanding and forecasting climate change are challenging, as climate is determined by a complex set of physical, chemical, and biological interactions among the atmosphere, the hydrosphere and lithosphere (Hartmann, 1994). It therefore suffices to state that understanding the dynamic influence of climate perturbations in these spheres both in real time and at synoptic level (for human adaptation) will require a synergy of data collection and analytical methods that are capable of capturing and processing data at a pace equal to or faster than those of the processes that lead to and the manifestations of climate change. Remote Sensing (RS) and Geographic Information System (GIS) have found wide application areas in climate change analyses and adaptation.

From a plethora of definitions, RS is defined in this study according to Janssen (2004) as the process of acquiring data on characteristics of the Earth's surface by a device (sensor) that is not in contact with the objects being measured and the processing of the data.GIS is the information tied to the earth's surface (including the zones immediately adjacent to the surface, and thus the subsurface, oceans, and atmosphere) (Longley et al., 1999).RS enables the acquisition of large-scale comprehensive datasets whereas GIS provides a means of displaying, overlaying, combining data from other sources and analysing the data (Chapman and Thornes, 2003).

The large collection of past and present RS imagery makes it possible to analyse spatiotemporal pattern of environmental elements and impact of human activities in past decades (Jianya et al., 2008). For climate change analysis, RS is a required tool for up-to-date environmental data acquisition both at local and synoptic levels. Scientists are now using satellite instruments to locate sinks and sources of CO2 in the ocean and land (Science, 2007). GIS on the other hand has a very important role to play in environmental monitoring and modelling for combining distributed field-based measurements and remotely sensed data (Larsen, 1999). Chapmann and Thornes (2003) submit that climatological and meteorological phenomena are naturally spatially variable, and hence GIS represents a useful solution to the management of vast spatial climate datasets for a wide number of applications.

Climate change adaptation is living with climate change. It is an automatic or planned response to climate change that minimises the adverse effects and maximises any benefits (Pittock, 2009). Strategies for climate change adaptation include loss bearing, loss sharing, climate change threat modification, effect prevention, change in land-use or activity, location change, furtherance of research on better methods of adaptation and behavioural change (Pittock, 2009). Going by the range of options of adaptation, it is rational to settle for prevention rather than cure. RS and GIS tools can help to capture and process relevant data for appropriate actions ahead of climate change events. This study reviews studies on the application of RS and GIS to climate and climate change analysis particularly looking at CO2 sinks and the trajectory of climate change effects.

II. Role of RS and GIS

2.1 Ice/Glacier Monitoring

The world-wide retreat of many glaciers during the past few decades is frequently mentioned as a clear and unambiguous sign of global warming (Oerlemans, 2006). Rapid recession of the ice cap, permafrost, and glaciers have been noticed in Mt Kilimanjaro, New Guinea and South America, Canada, the United States, China, Siberia, European Alps, among others, with accelerated environmental consequences (Pittock, 2009). Such include problems with roads, pipelines and buildings, threat to the stability of some mountain peaks and cable car stations, catastrophic release of water, among others (Pittock, 2009). Glaciers, ice caps, and ice sheets are important components of Earth's natural systems, very sensitive to climate change and difficult for scientists to measure in terms of mass balance. However, satellite images of the ice sheets can track their growth and recession over the years (Glacier, 2009).

Raup et al. (2007) reported the success of using RS and GIS in glacier monitoring and provision of global glacier inventory by Global Land Ice Measurements from Space (GLIMS). The study stated that GLIMS' glaciers monitoring involves the creation of a global glacier database of images such as ASTER, Landsat, Synthetic Aperture Radar (SAR), air photos, maps and derived data, and the analyses producing information are performed using a variety of methods including both automatic algorithms and manual interpretation in a distributed environment. Similarly, Bishop et al. (2004) had earlier reported the applicability and potential of RS/GIS in glacier monitoring by GLIMS. Field and satellite investigations were reported to have indicated many small glaciers and glaciers in temperate regions down-wasting and retreating. They concluded that RS/GIS and field investigations are vital for producing baseline information on glacier changes, and improving our understanding of the complex linkages between atmospheric, lithospheric, and glaciological processes.

In their view, Kaab et al. (2006) saw the need for the application of RS and GIS in glacier monitoring due to physical inaccessibility and remoteness of glacier hazard sources (mountain ranges), rapidity of human settlement expansion into areas historically unknown for glacier hazard occurrence and rapidity of glacier change. The study examined some glacier change risks such as glacier burst, glacier surge, displacement waves, overtopping of ice-dams, changing in run off and seasonality, para-glacial mass movement, ice and rock avalanche, among others and concluded that the assessment of glacier and permafrost hazards requires systematic and integrative approaches by the combination of RS, modelling with GIS or numerical models, geophysical soundings and other local field surveys.

Ye et al. (2006) studied glacier variations in the Geladandong mountain region of central Tibet using RS and GIS technics. Data from Landsat images at three different times, 1973–76, 1992 and 2002 were compared with glacier areas digitized from a topographic map based on aerial photographs taken in 1969. Findings showed that there was accelerated glacier retreat in recent years, attributable to increase in summer air temperature. Also, Rivera et al. (2012) studied the advance and retreat of tidewater glaciers of the Southern Patagonian ice field, Chile from satellite data. A recession of 19.5km length and 390m depth was noticed between 1898 and 2011, attributed to accelerating thinning rates and rapid ice velocities due to climate change.

Dai et al. (2012) measured snow depth and snow water equivalent from passive microwave remote sensing data based on a priori snow characteristics in Xinjiang, China. Using a novel snow depth/water equivalent (SWE) data retrieval algorithm from passive microwave brightness temperature, results obtained were consistent with the snow measurements at thirteen meteorological stations in Xinjiang, China from 2003 to 2010 and compared with existing SWE products from the National Snow and Ice Data Centre (NSIDC), the Environmental and Ecological Science Data Centre for West China (WESTDC) and the European Space Agency (ESA).

From the foregoing, RS and GIS tools are potentially useful for monitoring glaciers particularly in the advancement and recession mapping, measurement of mass balance, glacier inventory, glacier hazard monitoring, snow depth measurement, among others. As glaciers partially regulate atmospheric properties, sea level variations, surface and regional hydrology and topographic evolution (Bishop et al., 2004), information about them is very crucial for adaptation, and this can best be ensured by using RS and GIS.

2.2 Vegetation Change Monitoring

Vegetation provides a range of ecosystem services such as food and shelter for wildlife, and it controls the Earth's climate by regulating evapotranspiration and sequestration of carbon (May, 2007; Czerepowicza et al., 2012). Vegetation however is increasingly endangered mainly due to anthropogenic and climatic influences (Steven, 2001).World forests increasingly appear finite, vulnerable, dangerously diminished, perhaps already subject to irreparable damage (Steven, 2001). A most significant intellectual challenge to ecologists and biogeographers is to understand vegetation spatio-temporal patterns (Liu, 2007). RS is one of the widely used approaches for providing scientific evidence of vegetation change (Omuto, 2010). For example, Chen and Rao (2008) monitored vegetation using multi-temporal Landsat TM/ETM data in an ecotone between grassland and cropland in northeast China between 1988 and 2001. Classification and change detection carried out showed accelerated land degradation of the grassland around the salt-affected soil near the water bodies due to variation in water sizes as a result of both climate change and anthropogenic activities.

Omuto (2010) while tracing the footprint of vegetation dynamics modelled a relationship between Advanced Very High Resolution Radiometer (AVHRR) / Moderate Imaging Spectro-radiometer (MODIS) NDVI and rainfall using regression analysis. Results showed a high correlation between rainfall and NDVI which proved that vegetation trend monitoring with RS and GIS can give accurate indication of climate change. Li et al. (2008) assessed land-use/land-cover change pattern in Lake Qinghai watershed between 1977 and 2004 by combining Landsat MSS, TM and ETM data. Shrinkage in lake level and grassland degradation were discovered in the study area, with the first being attributed to climate change and the latter to anthropogenic disturbance.

Life on Earth is based on carbon, and the carbon cycle is the key to food, fuel, and fibre production for all living things (Steffen et al., 2005). Therefore, vegetation degradation will result in food insecurity and reduced carbon sequestration, thereby threatening human survival (Yelwa and Eniolorunda, 2012). The monitoring of vegetation degradation processes is an important component in developing appropriate conservation strategies aimed at landscape management for continued human existence (Ferraz et al., 2009). RS and GIS can suitably be used for characterizing vegetation phenology.

2.3 Carbon Trace/Accounting

As an eligible action to prevent climate change and global warming in post-2012 when Kyoto protocol expired (Kohl et al., 2011), Reduced Emission from Deforestation and Degradation (REDD+) was adopted in 2010 as a component under United Nations Framework Convention on Climate Change (UNFCCC) (Herold et al, 2011), requiring among other things, carbon accounting which involves taking forest carbon stock (Eckert et al., 2011). Studies have demonstrated the efficacy of RS and GIS in carbon accounting. Using a combination of field measurements, airborne Light Detection and Ranging (LiDAR) and satellite data, Asner et al. (2012) assessed high-resolution estimates of above ground carbon stocks in Madagascar. High carbon estimates were noticed in the remote areas while low estimates were recorded in areas of high human activities. The study concluded that high resolution mapping of carbon stocks is a veritable way of carbon monitoring as a climate change mitigation strategy. Similarly, Eckert et al. (2011) assessed aboveground biomass and carbon stock for low degraded forest and degraded forest in the Analanjirofo region, North East of Madagascar. Carbon stock within the two classes were calculated and linked to a multi-temporal set of SPOT satellite data acquired in 1991, 2004 and 2009 together with forest prediction for 2020 for the study area. These results are an important spatial information regarding the priorities in planning and implementation of future REDD+ activities in the area.

Ordonez et al. (2008) estimated the carbon content in vegetation, litter, and soil, under 10 different classes of land-use and land-cover classes (LU/LC) in the Purepecha Region, located in the Central Highlands of Mexico. Landsat ETM+ image of the year 2000 was classified to estimate the total area by the different LU/LC, while carbon data for each of the LU/LC classes and the main pools (vegetation, soil and litter) were collected at 92 sites in 276 field plots and analysed. The results of the study showed relevance for national inventories of carbon stocks and useful for derivation of greenhouse gas emissions (GHG). Similarly, Kronsedera et al. (2012) estimated the above ground biomass across forest types at different degradation levels in Central Kalimantan, Indonesia using LiDAR data. The study demonstrated the ability to quantify not only deforestation but also especially forest degradation and its spatial variability in terms of biomass change in different forest ecosystems using LiDAR. It Concluded that the combined approach of extensive field sampling and LiDAR have high potential for estimating carbon stocks across different forest types and degradation levels and its spatial variation in highly inaccessible tropical rainforests in the framework of REDD.

Alvaro-Fuentes et al. (2011) predicted soil organic carbon (SOC) stocks and changes in pasture, forest and agricultural soils in northeast Spain using the Global Environmental Facility Soil Organic Carbon (GEFSOC) system. The distribution of the different land-use categories and their change over time was obtained by using the Corine database and official Spanish statistics on land use from 1926 to 2007. The study show that

SOC in forest and grassland-pasture soils declined due to reduction in the soil surface occupied by both classes. The greatest SOC gain was predicted in agricultural soils caused by changes in management, which led to increases in C inputs. The study predicted that soil management in the area contributed to the sequestration of substantial amounts of atmospheric CO2 during the last 30 years. Golinkoff et al. (2011) used Airborne Laser Scanning (ALS) and optical remote sensing data to partition the variability across a forest in Mendocino County, CA, USA with a pixel-based forest stratification method. This approach improved the accuracy of the forest inventory, reduced the cost of field based inventory, providing a powerful tool for future management planning. The use of ALS and optical remote sensing data can help reduce the cost of field inventory and can help to locate areas that need the most intensive inventory effort.

2.4 Atmospheric Dynamics

Early civilian satellite instruments were launched largely to meet the needs of weather forecasting, among other applications (Sherbinin et al., 2002). Meteorological satellites are designed to measure emitted and reflected radiation from which atmospheric temperature, winds, moisture, and cloud cover can be derived. Hecker and Gieske (2004) listed a range of application of satellite data in the monitoring of atmospheric dynamics. According to them, RS can be used for the determination of the atmospheric radiances, emissivity and surface temperature. Burrows et al. (1998) measured the absorption cross-sections of NO2 using the global ozone monitoring experiment (GOME) flight model (FM) Satellite spectrometer. The spectra have a resolution of about 0.2 nm below 400 nm and of about 0.3 nm above 400 nm. The new absorption cross-sections are important as accurate reference data for atmospheric remote-sensing of NO2 and other minor trace gases.

Foster and Rahmstorf (2011) took a time series assessment of global temperature (over land and ocean) using three surface temperature records and two lower-troposphere temperature records based on satellite microwave. All the five series show consistent global warming trends ranging from 0.014 to 0.018Kyr−1 with 2009 and 2010 as the hottest years.

Jones et al (2010) demonstrate the application of Advanced Microwave Scanning Radiometer for EOS (AMSR-E) 18.7 and 23.8GHz and polarized brightness temperatures for deriving daily 2-m height air temperature minima and maxima over land with minimal ancillary Land cover, elevation and weather station temperature readings. The algorithms and results of the study are sufficiently accurate for regional analysis of air temperature patterns and environmental gradients, and are appropriate inputs for atmospheric and land surface models.

Aumann et al. (2011) separated a window channel and a channel with strong CO2 absorption from cold cloud data in the tropical oceans from Atmospheric Infrared Sounder AIRS, Advanced Microwave Sounder Unit (AMSU) and the Advanced Microwave Scanning Radiometer for EOS (AMSRE). Brightness temperatures directly observed from AIRS and AMSU are indicative of local distortion of the tropopause associated with severe storms, the statistical long term trend of which could be linked to climate change.

Bogumil et al (2003) demonstrated the measurement of atmospheric trace gas absorption spectra using the Scanning Imaging Absorption Spectrometer for Atmospheric Chartography (SCIAMACHY). Gas-phase absorption spectra of the most important atmospheric trace gases (O3, NO2, SO2, O2, OClO, H2CO, H2O, CO, CO2, CH4 and SO4) were measured. The spectra show high signal-to-noise ratio, high baseline stability and an accurate wavelength calibration. The study concluded that the results are important as reference data for atmospheric remote-sensing and physical chemistry.

2.5 Terrestrial Temperature Monitoring

Evapotranspiration (ET) is an important part of the planet's hydrological cycle, and it is likely to change in a warming world as it is highly increased by high temperatures (Michon, 2008b). Accurate ET estimation enables improvements in weather and climate forecasts, flood and drought forecasts, predictions of agricultural productivity, and assessment of climate change impacts (Sun et al., 2012). Hecker and Gieske (2004) posited that satellite data can be used for the determination of surface emissivity and temperature, rock emissivity mapping and thermal hotspot detection such as forest fires or underground coal fires, or to volcanic activity. Bradley et al. (2002) modelled spatial and temporal road thermal climatology in rural and urban areas of west midlands UK using satellite land cover classification, field analysis of urban canyon characteristics, physical variables of albedo, emissivity and surface roughness within a GIS environment. It was suggested that the busier a stretch of road the likelier it is to have a higher road surface temperature and smaller diurnal range. Road surface temperature forecast especially in the winter months is essential for highway road ice formation monitoring.

In their study, Sun et al. (2012) estimated evapotranspiration from MODIS and Advanced Microwave Scanning Radiometer - Earth Observing System (AMSR-E) land surface temperature and moisture over of the Southern Great Plains. Spatial patterns of modelled ET and of key model parameters indicate that radiation and moisture availability are the controlling factors on ET in the study area. The spatial distributions of the estimated parameters appear reasonable: they are smooth and not overly patchy or random; and they are consistent with the land cover and soil moisture distribution through the area. Sutton et al. (2010) submitted that Night-time satellite imagery captures radiation primarily from lightning, fires and most importantly: human sources such as city lights, lantern fishing, and gas flare burns.

Anderson and Kustas (2008) derived land surface temperature (LST) from remote sensing data in the thermal infrared (TIR) band (8–14 microns) to diagnose of biospheric stress resulting from soil moisture deficiencies. The study concluded that TIR imagery can serve as an effective substitute for precipitation data, providing much needed water information in data-poor regions of the world.

2.6 Erosion Monitoring and Control

Soils are the second largest terrestrial carbon (C) reservoir, containing about 3.3 times the amount of C in the atmospheric pool and 4.5 times that in the biotic pool (Jia et al., 2012). This reservoir becomes a carbon source as the rate of organic matter decomposition increases through erosion (Bridges and Oldeman, 1999). Water erosion is the most significant type of soil degradation in all continents, except in western Asia and Africa where water and wind erosion are almost of equal significance (Sentis, 1997; Bridges and Oldeman, 1999). These are initiated by human overexploitation of natural resources (Bridges and Oldeman, 1999). However, intensive use of natural resources calls for increasing detailed inventories (Adeniyi, 1993; Solaimani et al, 2009). Santillan et al. (2010) integrated RS, GIS and hydrologic models to predict land cover change impacts on surface runoff and sediment yield in a watershed of Philippines. The method quantifiably predicted the potential hydrologic implications useful for planners and decision makers as a tool for evaluating proposed land cover rehabilitation strategies in minimizing runoff and sediment yield during rainfall events in the ecosystem.

Goovaerts (1998) incorporated a digital elevation model (DEM) into the mapping of annual and monthly erosivity values in the Algarve region Portugal. The combination of simple Kriging, Kriging with an external drift and co-Kriging method of interpolation allowed for modelling sparse rainfall data in the study area, allows for a good computation of the erosivity estimate. The relationship between LU/LC change and erosion was established and predicted for a fast agricultural land of Neka River Basin, Iran by Solaimani et al (2009). The study combined topographical, geological, land use maps and satellite data of the study area within the GIS environment to model erosion. Results indicated decreased sediment yield after an appropriate LU/LC alteration. This result highlights the potency of the tool for land management practice.

Mohammed and Abdo (2011) assessed the impact of El-Multagha agricultural project on some soil physical and chemical properties in Sudan. Soil samples were taken with Global Positioning System (GPS) receiver and soil properties determined. Kriging was used to interpolate a continuous surface for each of the properties within the GIS environment. Results showed that the soils are generally saline and texture varied from clay to clay loam. GIS was found to be very useful for soil survey and precision farming.

2.7 Ocean and Coastal Monitoring

Climate variability modifies both oceanic and terrestrial surface CO2 flux with resultant strong impacts on the land surface temperature and soil moisture (Okajima and Kawamiya, 2011). Sea surface temperature (SST), El Nino, sea level, biomass, precipitation, surface wind and sea surface height relative to the ocean geoid are important features that determine global weather conditions (Janssen, 2004; Issar and Zohar, 2007). These can be captured very easily by satellite in space (Janssen, 2004). A number of studies have demonstrated the applicability of RS and GIS in this regard. For example, Kavak and Karadogan (2011) investigated the relationship between phytoplankton chlorophyll and sea surface temperature of the Black Sea, using Seaviewing Wide Field-of view Sensor (SeaWiFS) and Advanced Very High Resolution Radiometer (AVHRR) satellite imagery. The study discovered a high correlation between sea surface temperature and chlorophyll for the same time, and it concluded that the information could be useful in connection with studies of global changes in temperature and what effect they could have on the total abundance of marine life.

Kazemipour et al. (2012) applied hyper-spectral images of Bourgneuf Bay (French Atlantic coast) to Micro-phytobenthos biomass mapping. The method used was capable of detecting and quantifying the main assemblages of micro-phytobenthos at the ecosystem scale. Such a robust modelling approach is also suitable for tracking and temporal monitoring of the functioning of similar ecosystems. Monitoring of microphytobenthos can help determine the effect of climate change.

Politi et al. (2012) characterise temporal and spatial trends in water temperature of large European lakes using NOAA Advanced Very High Resolution Radiometer (AVHRR) thermal data. Validation of the approach using archived AVHRR thermal data for Lake Geneva produced observations that were consistent with field data for equivalent time periods. This approach provides the potentiality of using RS and GIS to monitor the trajectory of lake water change with respect to climate change and anthropogenic effects.

2.8 Biodiversity Conservation

Livelihood primarily depends on the rich landscape biodiversity which today is largely bedevilled by environmental uncertainties, arising from climate change linked global warming and globalization of economies (Ramakrishnan, 2009). Palminteri et al. (2012) used airborne waveform light detection and ranging (LiDAR) data in combination with detailed field data on a population of bald-faced Saki monkeys (Pitheciairrorata) to assess the canopy structure in describing parameters of preferred forest types in the south eastern Peruvian Amazon. Results provide novel insights into the relationship between vegetation structure and habitat use by a tropical arboreal vertebrate, highlighting capability of RS in predicting habitat occupancy and selection by forest canopy species.

Bino et al (2008) used remote sensing tools to predict bird richness in the city of Jerusalem. Bird richness was sampled in 40 1-ha sites over a range of urban environments in 329 surveys. NDVI and the percentage cover of built-up area were strongly negatively correlated with each other, and were both very successful in explaining the number of bird species in the study sites. It was suggested that remote sensing approaches may provide planners and conservation biologists with an efficient and cost-effective method to study and estimate biodiversity across urban environments that range between densely built-up areas, residential neighbourhoods, urban parks and the peri-urban environment.

2.9 Drought and Desertification

Kassas (1994) defined drought as a situation when annual rainfall is less than normal, monthly/seasonal rainfall is less than normal and when river flow and ground water availability is decreased. Desertification is decline in the biological or economic productivity of the soil in arid and semiarid areas resulting from land degradation due to human activities and variations in climate (Hutchinson, 2009). Jeyaseelan (2003) stated that satellites provide continuous and synoptic observations over large areas having the advantage of providing much higher resolution imageries, which could be used for detailed drought and desertification monitoring, damage assessment and long-term relief management. Advancements in the RS technology and the GIS help in real time monitoring, early warning and quick damage assessment of both drought and flood disasters (Jeyaseelan, 2003).

Laughlin and Clark (2000) submitted that data from NOAA Advanced Very High Resolution Radiometer (AVHRR), Landsat, SPOT and RadarSat are used operationally in the assessment of drought, frost impact on crop production and flooding in Australia.

Kogan (2000) tested the new numerical method of drought detection and impact assessment from NOAA operational environmental satellites and validated the outcome against conventional data in 25 countries, including all major agricultural producers. The study discovered that drought can be detected 4-6 weeks earlier than before and delineated more accurately, and its impact on grain production can be diagnosed far in advance of harvest, which is the most vital need for global food security and trade.

Sun et al. (2007) used GIS calculated Cost-distance connectivity measure with a 1997 land use map to indicate desertification in Minqin County, China. The application of connectivity based on cost-distance provides a straightforward, easily visualized description of desertification. It was concluded that desertification assessments using this method could be achieved at regional level for planning and decision-making. Collado et al (2002) used two Landsat images acquired in 1982 and 1992 to evaluate the potential of using RS analysis in desertification monitoring. Analysis revealed dune movement, re-vegetation trends and variations in water bodies, as a result of changing rainfall and land use patterns.

Yelwa and Eniolorunda (2012) simulated the spatial trend of desertification in Sokoto and its environs, Nigeria, using a time series 1-km SPOT Normalized Difference Vegetation Index (NDVI) and GIS. Results showed the direction of desertification movement and that the inter-annual vegetation vigour exhibited a diminishing trend over the time series.

2.10 Health and Disease

Scientific evidence have shown that climate change has serious health impact - the reason for the Sixtyfirst World Health Assembly's work-plan for scaling up WHO's technical support to Member States for assessing and addressing the implications of climate change for health and health systems (WHO, 2009). Climate change events such as flood, storm, and heat-waves cause short- and medium-term diseases, while drought and desertification can limit poor people's access to safe water (Haines, 2008). Severe changes in temperature and weather (floods and storms) can cause food poisoning, respiratory problems from the damage to surface ozone during the summer and mould growth in homes, skin cancer and cataracts, insect-borne disease from an increase in flies and fleas and psychological stress (North Yorkshire and York, 2011). Remote sensing is primarily used in the context of disease mapping, in which statistical associations are demonstrated between ecological variables and processes that can be observed remotely (e.g., rainfall, temperature, vegetation cover, wetness, etc.) (Sherbinin, 2002). Vector-borne infections are geographically restricted by climate and topography which can be modelled using GPS, RS and GIS (Chapmann and Thornes, 2003).

Siri et al. (2008) produced a quantitative classification of Kisumu, Kenya, for malaria research using seven variables, having known relationship with malaria in the context of urbanization together with Satellite and census data. Principal Components Analysis (PCA) was used to identify three most potent factors of malaria epidemiology in the study area. The method was found effective for malaria epidemiology and control in related urban areas.

Koita et al. (2012) examined the seasonality of malaria parasite prevalence in the dry northern part of Mali at the edge of the Sahara desert. Results showed lower prevalence in hot dry than cold dry, Malaria remained stable in the villages with ponds but varied between the 2 seasons in the villages without ponds Malaria was meso-endemic in the study area. Sudhakar et al. (2006) used a combination of RS and GIS approach to develop landscape predictors of sandfly abundance. Result showed that rural villages surrounded by higher proportion of transitional swamps with soft stemmed edible plants and banana, sugarcane plantations had higher sandfly abundance and would, therefore, be at higher risk prone areas for man-vector contact.

2.11 Flood Monitoring

Climate change is expected to increase the risk of flooding for people around the world, both by raising global sea levels and increasing severe inland flooding events, hence there is continuous desire to predict flooding (Michon, 2008a). Sanyal and Lu (2004) submitted that the conventional means of recording hydrological parameters of a flood often fail to record an extreme event, thus RS and GIS become the key tool for delineation of flood zones and preparation of flood hazard maps for the vulnerable areas. Islam and Sado (2000) developed flood hazard maps for Bangladesh using RS data for the historical event of the 1988 flood with data of elevation height, and geological and physiographic divisions. Abas et al. (2009) successfully demonstrated the potential of using GIS for flood disaster Management for Allahabad Sadar Sub-District (India). The flood-prone areas were identified and various thematic maps include road network map, drinking water sources map, land use map, population density map, ward boundaries and location of slums were generated and stored for management and decision making.

Brivio et al. (2002) used two ERS-1 synthetic aperture radar (SAR) images (before and after) and ancillary topographic information to detect flooded areas at their peak and evaluated its potential with mapping using the flood that occurred in Regione Piemonte in Italy in November 1994. After processing and interpretation, flood map derived accounted for 96.7% of the flooded area, making the procedure suitable for mapping flooded areas even when satellite data are acquired some days after the event, thus overcoming the constraint of temporal resolution in the application of SAR imagery in hydrology.

gy. Ifabiyi and Eniolorunda (2012) assessed the watershed Characteristics of the Upper Sokoto Basin, Nigeria using RS and GIS. 44 variables generated showed that the basin has a high propensity of being flooded, recommending construction of levees to protect farmlands, efficient reservoir operation and sustainable watershed management for the purpose of environmental management in the basin.

2.12 Agriculture

Lal (2009) averred that soil quality, water availability or drought stress and climate change are three biophysical factors which need to be addressed for food security in the face of climate change. RS and GIS have been found useful for soil characteristics mapping, agro-climatic assessment, land use suitability for crop production, irrigation management, precision farming, crop type mapping, crop condition assessment, among others.

Satellite data provide a real-time assessment of crop condition. Ines et al. (2006) combined Landsat7 ETM+ images and derived distributed data such as sowing dates, irrigation practices, soil properties, depth to groundwater and water quality as inputs in exploring water management options in Kaithal, Haryana, India during 2000–2001 dry season. Results showed that under limited water condition, regional wheat yield could improve further if water and crop management practices are considered simultaneously and not independently.

Santhi et al. (2005) used GIS based hydrological model for estimating canal irrigation demand in the Lower Rio Grande Valley in Texas. Estimated potential water savings were 234.2, 65.9, and 194.0 Mm3 for conservation measures related to on−farm management improvements. It concluded that GIS would be useful for irrigation planning. Bakhsh et al. (2000) combined yield records, farm input and soil attributes within the GIS environment to investigate the relationship between soil attributes and corn (Zea mays L.)-Soybean (Glycine max L.) yield variability using four years (1995-98) yield data from a 22-ha field located in central Iowa. It was concluded that interaction of soil type and topography influenced yield variability of this field. Frolking et al. (2002) combined county-scale agricultural census statistics on total cropland area and sown area of 17 major crops in 1990 with a fine-resolution land-cover map derived from 1995–1996 optical remote sensing (Landsat) data to generate 0.50 resolution maps of the distribution of rice agriculture in mainland China.

Haboudane (2002) combined modelling and indices-based approach to predicting the crop chlorophyll content from remote sensing data. Result showed chlorophyll variability over crop plots with various levels of nitrogen, and revealed an excellent agreement with ground truth, with a correlation of r 2=.81 between estimated and field measured chlorophyll content data.

III. Conclusion

Basic terms tied to climate change have been explained in this study. Also highlighted are some areas where RS and GIS are applicable in climate change analysis and adaptation but the study has by no means covered all the possible areas of application of the tools in the subject matter. Issues considered in this review are snow/glacier monitoring, land cover monitoring, carbon trace/accounting, atmospheric dynamics, terrestrial temperature monitoring, biodiversity conservation, ocean and coast monitoring, erosion monitoring and control, agriculture, flood monitoring, health and disease, drought and desertification. This review has shown from all cited examples that climate change will be less understood or managed without the application of RS and GIS.

As the earth's system is continuously heating up by the year unavoidably due to anthropogenic emission of GHGs, more and more researches are being expanded into discovering efficient ways of sequestering CO2 from the atmosphere as the only way to prevent global warming. However, in the interim, climate change analysis will continue to benefit from the plethora of data volume generated by air and space vehicles and the sustained advancement in space and computer technology, thereby making RS and GIS play a crucial role in tracing the trajectories of climate change and its effects for human survival.

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