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Climate Risk Analysis for Financial Institutions

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Synonyms

Carbon Finance; Carbon Trading; Carbon Emissions; Emissions Trading; Climate Change; Sustainability Risk; Climate Finance; REDD+; MRV; GIS Mobile Remote Sensors; GHG; Sequestration; Climate Trend Analysis

Definition

The climate change phenomenon is widely understood to be magnified by harmful greenhouse gases (GHGs) that are by-products of emissions yielded from advances in human engineering in the energy, technology, transportation, and land development industries. Effectively, the pollution that is being generated from human activities is actively contributing to the imbalance in the planet's climate, therefore creating the scenario where human prosperity may be severely hindered in the near future. Global industrial incentives, regulations, and policies have been formed to mitigate the climate change phenomenon in the form of monetized financial instruments that can help manage the amount of global pollution permitted, financial climate risk disclosures that keep investors informed about climate-related impacts to investments, and environmental sustainability analysis that validates the business continuity of an investment impacted by environmental risks.

The management of future pollution that may contribute to furthering climate change by financially incentivizing more prudent business practices and climate-friendly organizational strategies has created opportunities for climate change investment research. Geographical Information Systems that can provide insight into different aspects of global climate change facilitates data-driven financial investment decisions which can create a dynamic and robust relationship between the financial and scientific aspects of leveraging climate change mitigation.

This chapter will explore the historical background of global climate change polices and legislation over recent decades; the financial instruments, markets, and risk disclosures that resulted from these policies; the relevant scientific and investment approaches regarding climate change mitigation; how Geographical Information Systems can serve as a crucial tool in the financial applications of climate change mitigation and the future prospects of Geographical Information Systems in this domain.

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Historical Background

United Nations Climate Mitigation Polices

The environmental impacts of climate change were not clearly understood by the nations of the world in the early 1980s. The United States was the first government to lead an exploratory study of international environmental risks which included a thorough analysis on climate change effects. This study brought significant awareness to the potential impacts of climate change warranting a more specified scientific study of climate change to illuminate the future risks that nations of the world may have to encounter (Moore 2012).

In 1988, the United Nations World Meteorological Organization (WMO) and the United Nations Environment Program (UNEP) established the Intergovernmental Panel on Climate Change (IPCC) to provide research on the science of climate change, analyze the societal and economical risks due to climate change, and produce strategies to mitigate the impacts that climate change presents for further discussion on the international topic (Moore 2012).

The first assessment report from the IPCC was delivered on 1990 and provided ample evidence to suggest that climate change would be of crucial importance for the near future of environmental risks and policy planning. With subsequent reports from the IPCC echoing similar sentiments and additional evidence supporting the analysis, it was decided at the 1992 United Nations Conference on Environment and Development (UNCED) to formally begin action to create policies for climate change mitigation by commissioning the United Nations Framework Convention on Climate Change (UNFCCC) (Moore 2012; Raufer and Iyer 2012).

The purpose of the UNFCCC was to establish a voluntary commitment from the United States and 153 other nations to reduce harmful greenhouse gas (GHG) emissions to environmentally acceptable levels within the next few decades, to find strategies to reduce the global warming epidemic, and to assess viable options to address inevitable climate change effects on the environment (Moore 2012; Raufer and Iyer 2012). Annual meetings of the parties involved with the UNFCCC have been conducted since the inception of the convention onward, formally referred to as the UNFCCC conference of parties (COP), yielding progressive legislation and policies toward the mitigation of climate change (Moore 2012).

The meetings of most significant and considered progressive milestones for climate change mitigation policies have been that of the COP of 1997 in Kyoto, Japan, and the COP of 2009 in Copenhagen, Denmark (Moore 2012; Raufer and Iyer 2012; Alexander 2013).

Kyoto Protocol

On December 11, 1997, during an annual UNFCC COP in Kyoto, Japan, the Kyoto Protocol was adopted and given an effective date of February 16, 2005. The Kyoto Protocol is widely seen as the first significant step toward an internationally standardized GHG emissions reduction plan that seeks to manage harmful emissions and provide a formalized scalability platform to continuously improve on climate change mitigation strategies (Moore 2012; Raufer and Iyer 2012; Baranzini and Carattini 2014).

The Kyoto Protocol facilitated the reduction of emissions by the establishment of binding agreements among 37 industrialized nations and European nations which committed the nations to reduce their GHG emissions output by an average of about 5–8 % from the year 1990 emissions output by a 5-year span of 2008–2009 (Moore 2012; Raufer and Iyer 2012; Baranzini and Carattini 2014). More importantly, the Kyoto Protocol placed a larger responsibility and burden on the developed countries due to the accepted notion that they were the primary contributors to the current amount of GHG emissions in the atmosphere (Moore 2012).

Enforcement of the Kyoto Protocol was generally conducted through industrial policies and regulations at the federal and local government levels of each respective participatory nation (Moore 2012). However, the Kyoto Protocol also offered market-based financial and economical incentives to achieve promotion of environment-friendly investments, business practices, and technologies as well as to meet GHG reduction targets via economic and efficient options. The market-based options that the Kyoto Protocol introduced were GHG Emissions Trading, the Clean Development Mechanism (CDM), and the Joint Implementation (JI). Each of the options followed a cap and trade framework in which there was a "cap" or quota on the allowed amount of commodities (emissions allowed to be produced) that were in the market. The "trade" aspect refers to the ability and platform to trade the commodities as an instrument with other market participants (Moore 2012; Raufer and Iyer 2012; Baranzini and Carattini 2014; Henríquez 2013; Kossoy and Guigon 2012).

Greenhouse Gas Emissions Trading

As previously mentioned, the Kyoto Protocol receives commitments from participatory nations to reduce GHG emission levels by a 5-year span in 2008–2012. Some countries may be able to facilitate these targets while being well under target emissions levels, but some may require additional allowance of emissions to meet practical industrial and economic demands. To address this potential issue, Article 17 of the Kyoto Protocol allows for different market-based financial instruments that can allow for trade of excess emissions allowances to countries that may exceed emissions targets (Raufer and Iyer 2012; Baranzini and Carattini 2014; Henríquez 2013; Kossoy and Guigon 2012).

The provision in the Kyoto Protocol also allows the trade of other equally important environmental reduction targets such as the removal units (RMU) based on land use, land use change, and forestry (LULUCF) activities to help mitigate deforestation activities which directly contribute to the natural mitigation of climate change (Moore 2012). Additionally the Kyoto Protocol also offers the global Clean Development Mechanisms that acts as the authority of GHG emissions offset programs which allows industrialized or developing countries that engage in qualified local projects that are designed to help reduce GHG emissions or to provide environmental sustainability to earn certified emissions credits (CER).

A CER is the equivalent of 1 ton of carbon dioxide (CO_2) allowed to be emitted into the atmosphere. CO_2 is one of the harmful GHG emissions that contributes to climate change. With these earned CER credits, they can be traded, sold, or purchased on international markets for the benefit of nations to meet or exceed their GHG emissions reduction targets (Moore 2012; Raufer and Iyer 2012). It is also important to note that 2 % of the income proceeds from CDM projects goes toward the Kyoto Protocol Adaptation Fund which financially backs projects and programs for countries that are impacted most adversely from climate change effects without the ability to mitigate them (Moore 2012). Lastly, the Joint Implementation provision in the Kyoto Protocol under Article 6 allows participating nations to engage in qualified projects that reduce GHG emissions in other countries to earn emissions reduction credits which can be used toward the participatory nations GHG emissions reduction targets. Joint Implementations allows for mutually beneficial partnerships that help to foster prosperity in developing nations while also keeping a focus on the mitigation of climate change (Moore 2012). It is important to note that all of these market-based mechanisms are heavily dependent on accurate analysis, measurement, and forecasting of GHG emissions to be considered a viable climate change mitigation strategy (Raufer and Iyer 2012; Rosenqvist et al. 2003).

GHG emissions trading relies on the overall calculated emissions quotas for each respective nation to determine the appropriate amount of commoditized GHG emissions to be allowed into the market. For this market-based platform to be successful, accurate monitoring and measurements of actual GHG emissions from each nation is required though regulated carbon registries and authorities (Moore 2012; Rosenqvist et al. 2003).

Once regulated appropriately and accurately, national and regional marketplaces are allowed to be established so long as they follow the Kyoto Protocol's fundamental stipulations. This has allowed for emissions marketplaces such as the then Chicago Climate Exchange (CCX) and European Climate Exchange (ECX), both of which operated as a trading platform similar to that of other financial commodities exchanges, and now the Intercontinental Exchange Futures Europe which is now the leading market in emissions trading. All of which followed the European Union's emissions trading scheme (EU ETS) (Raufer and Iyer 2012; Baranzini and Carattini 2014; Rosenqvist et al. 2003; Kossoy and Guigon 2012).

Reducing Emissions from Deforestation and Forest Degradation

At the 11th Conference of Parties (COP11) of the UNFCCC in the year 2005, the reducing emissions from deforestation and forest degradation (REDD) program was established to assist with the reduction of carbon emissions and preservation of the forests (Alexander 2013; Tänzler and Ries 2012). The program was initially developed to support the Clean Development Mechanism (CDM) policies under the Kyoto Protocol to allow developing countries to gain funds for projects focused around the conservation, afforestation, and reforestation leading to the reduction of GHG emissions. The IPCC had earlier concluded that the continual degradation of terrestrial and wetland forests has direct impacts on the mitigation of climate change (Alexander 2013; Tänzler and Ries 2012; Plugge et al. 2011; Nzunda and Mahuve 2011; Wertz-Kanounnikoff et al. 2008). At the 12th Conference of Parties (COP15) of the UNFCC in the year 2007, the Bali Action Plan was ratified, yielding the REDD+ program (REDDplus). REDD+ included all of the original REDD stipulations but also incorporated a focus on funding projects that created sustainable management of forests and further enhancement of forest carbon stocks in developing countries (Alexander 2013). REDD+ programs are based on the science that terrestrial forests, wetland forests, and biodiversity are capable of natural carbon sequestration, where GHG emissions such as carbon dioxide (CO_2) is captured by plant life and where carbon is stored in the soil beneath the plant life (Alexander 2013; Tänzler and Ries 2012; Plugge et al. 2011; Nzunda and Mahuve 2011; Wertz-Kanounnikoff et al. 2008).

Copenhagen Accord

As the Kyoto Protocol's framework approached its expiration date of 2012, a mounting need to develop a new framework that may extend and/or enhance the Kyoto Protocol's principles for climate change mitigation was direly needed. The December 2009 United Nations Climate Change Conference in Copenhagen, Denmark, addressed the concerns of the expiration of the Kyoto Protocol by developing, negotiating, and ratifying the Copenhagen Accord. The Copenhagen Accord committed 186 nations (including the United States) to reduce GHG emissions levels, engage in clean energy projects, and put focus on adaptation projects due to the impacts of climate change. The Copenhagen Accord also requests a technical analysis due in 2015 to determine the need of a new potential CO_2 atmospheric concentration level to maintain to achieve the underlying goals behind climate change mitigation (Moore 2012). The main highlights of the Copenhagen Accord included continued action by countries to manage global temperature increases to under 2 °C, submission of GHG emissions reduction goals by January 2010 from each participatory country, reports from developing countries about climate mitigation actions, and financial funding for environmental conservation projects in developing countries (Moore 2012). The Copenhagen Accord also stipulates that the UNFCCC will continue its role for financial governance, GHG emissions reporting and monitoring, and scientific climate analysis for the years beyond the expiration of the Kyoto Protocol and will conduct meetings as necessary to achieve appropriate mitigation of climate change (Moore 2012).

Scientific Fundamentals

Given the importance of the climate change phenomenon evidenced by the international climate change mitigation policies mentioned in the previous section, a substantial focus on accurately assessing, measuring, forecasting, and validating the variables of climate change emerges. All the policies and strategies to mitigate climate change fundamentally require measurement and validation methodologies in order to succeed. The fundamental scientific approaches to analyzing climate change and its mitigation provide a key perspective of the future and how to maneuver accordingly to adapt to the potential impacts from climate change.

Proper scientific analysis can benefit all stakeholders within the climate change mitigation framework by providing relative perspective and data interpretation that can potentially drive strategic decisions. This section will briefly review the popular scientific methods that examine aspects of climate change and its mitigation.

Climate Trend Analysis

Climate can be defined as the weather conditions that reveal over an arbitrary period of time, which is usually supported through conventional statistical analysis or statistical diagnostics. Trend, relative to climate, can be defined as the gradual differences of certain climate-related variables over some period of time (Shea 2014).

Traditional statistical time series analysis can be conducted on temperature changes, rainfall measurement, snow patterns, and flooding, and other climate change indicators to detect, estimate, and predict possible emerging climate trends are significant scientific tools to better understand climate change (Shea 2014).

More advanced statistical techniques can be applied to derive more specific data analysis, such as Taylor diagrams, to graphically compare statistical correlation summaries between individual climate patterns(observed or modeled), empirical orthogonal function(EOF), and rotated EOF analysis to interpret potential spatial modes or patterns of variability changes over time (Shea 2014).

All the fundamental Climate Trend Analysis techniques are important for statistical analysis and modeling that can help produce climate change projections for the near future. These projections directly impact climate change mitigation policies, adaptation projects, and business decisions of respective stakeholders.

Surface and Air Temperature Analysis for Land and Sea

Measurements of land air temperature and sea surface temperature (SST) are of significant importance to understand climate conditions in respective regions. This is evidenced by the many decades of available data of the measurements that exist previously to the climate change mitigation conversation. These measurements can provide the data necessary to corroborate findings from climate data models by serving as the ground truth validation source (Hansen et al. 2006). More importantly, the temperature measurements over land and sea can be coordinated in a spatiotemporal plane for pattern analysis, data modeling, and statistical analysis.

Land surface air temperature weather stations are usually stationed in strategic locations throughout a specified region to collect appropriate data and summarize as the highest and lowest temperature recorded for a particular day, which is then reported to a central station which may collect the raw data and combine it with other regional surface temperature weather stations for further analysis. Appropriate standards are followed in the placement of the temperature sensors which ensure they are impartial to influences that may be in close proximity (Hansen et al. 2006).

Similarly, sea surface temperatures (SST) can be collected by remote stations on ships or buoys equipped with sensors that take measurements of the water surface and summarize the highs and lows of daily water temperature and levels which can be later polled and combined at a central station (Reynolds et al. 2007). Climate scientists rely on statistical anomaly analysis of the water temperature and levels to assess potential inclement weather in the form of cyclones, hurricanes, and tropical storms. With the mentioned techniques, climatologists can develop statistical models that can help estimate, detect, and project future weather patterns (Reynolds et al. 2007).

Satellite resolution imaging may give a broader, less granular depiction of the overall temperature ranges worldwide to help focus on particular patterns or regions of interest, but they are unable to produce the amount of detail that surface level temperature sensors can provide (Kungvalchokechai and Sawada 2013).

The monitoring and analysis of land surface temperature is scientifically linked to the planet's weather and climate patterns, which can be a direct result of increasing atmospheric GHGs. The temperature increases in certain regions can have effects on global glaciers, arctic ice sheets, and vegetation on the planet. Accurately understanding the aspects of the surface temperatures can give scientists a clearer picture about adaptation needs and climate impact projections.

Emissions Analysis

The term greenhouse gases emissions refer directly to the emissions produced from industrial processes, transportation by-products, agricultural by-products, and societal waste products. The gases in questions are the following: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), perfluorocarbons ($PFCs$), hydrofluorocarbons ($HFCs$), sulfur hexafluoride (SF_6), as well as the indirect gases that will not be mentioned here (Raufer and Iyer 2012). As mentioned in the previous section, the success of climate change mitigation policies rely directly on the accurate measurements of past, present, and future GHG emissions that could reach the atmosphere, thereby increasing the global temperatures.

GHG emissions control stipulated from climate change mitigation policies require monitoring sensors that can accurately audit the amount of GHG emissions produced. These policies are driven by the science that each GHG has a direct impact on the climate change to the planet. These greenhouse gases that are emitted to the atmosphere create a barrier which does not allow solar heat received from the sun to escape the planet's atmosphere once it has reached surface level, thereby increasing the climate (Myhre et al. 2013).

Scientific methods to derive the atmospheric lifetime, which is the amount of time a gas may stay in the atmosphere; GHG concentrations, which are the estimated values measured in respective until current GHG emissions in the atmosphere; radiative forcing, which is the amount of heat energy the gases absorb and keep in the earth's atmosphere rather than allow it to leave back to space; and global warming potential (GWP), which is the a derived ratio from the atmospheric lifetime and radiative forcing over a specified timescale to determine the impact of the gas on global warming relative to carbon dioxide (CO_2); give climate scientists quantifiable metrics to weigh and assess the impact of each GHG emission to appropriate mathematical models and climate data models (Myhre et al. 2013). These methodology and analysis give climate scientists quantifiable terms to weight and assess the different intensities and impacts of each GHG emission to appropriate mathematical models and climate data models. An important note about emissions that impact climate change include both natural (water vapor) and anthropogenic (pollution or pollutants from human activity) sources which both need to be accurately quantified and analyzed (Myhre et al. 2013).

Carbon Capture and Sequestration Analysis

The term carbon sequestration refers to the natural or synthetic process of capturing and/or storing carbon dioxide (CO_2) emissions, thereby mitigating climate change by reducing the amount of the GHG emission to reach or remain in the atmosphere. The natural process of achieving a balance of CO_2 emissions and climate change comes in the form of forested wetlands, terrestrial forests, and plant life, all of which have the capability to capture CO_2 emissions for consumption and store carbon into the soil which their roots are deeply entrenched (Freedman 2014; Alexander 2013). The synthetic process captures carbon-based emissions at the point of production from industrial facilities that produce the emissions and transport it deep underneath land or sea where it may dissolve or be stored indefinitely (Katzer et al. 2007).

Both the natural and synthetic carbon sequestration processes require accurate calculations and depictions of the amount of CO_2 being captured and/or stored to determine the effectiveness of the mitigation (Freedman 2014; Alexander 2013; Katzer et al. 2007). To achieve this feat synthetically, scientists need to mathematically calculate the amount of CO_2 in units of metric tons that can be properly captured and stored under the planet's land and sea without causing adverse effects to the environment. The terrestrial or natural approach would require scientists to determine the amount of CO_2 that plant life from forested areas can capture and store the emissions to achieve a substantial mitigation to climate change (Freedman 2014; Katzer et al. 2007). This is evidenced by the ratification of the REDD+ policy mentioned in the previous section.

Geographical Information Systems

The scientific analysis techniques, data sources, and respective stakeholder interests in climate change mitigation have created a demand for platforms that can dynamically bring together the different aspects that are required to perform effective climate change mitigation analysis. Advances in information technology, accessibility to data sources, and economic costs of data storage have allowed for the availability of Geographical Information Systems (GIS) platforms to be developed for robust analysis requirements of climate change mitigation research. GIS serves as a tool for scientific-based climate research by practically combining the many different scientific analysis techniques with appropriate data streams and visualizations to provide data-driven insights for climate change stakeholders.

Geographical Information Systems can be developed and customized to successfully achieve the feature requirements for different climate analysis purposes, but some of the conceptual fundamentals that a GIS system developed to analyze climate change usually revolve around the following abilities.

Mapping

A GIS system for climate change analysis should have the ability to render a data canvas of the geographical region of interest or global map where data overlays can be produced based on appropriate data streams to represent appropriate depictions of the said data.

Gridding and Regridding

Gridded data can be high-resolution images of a certain geographical region that does not give the total perspective of surrounding regions due to computational or storage limitations. Segments or fragments of a larger overall high-resolution image are provided, which is a part of a sequenced grid of neighboring images that can be examined individually. Due to the nature of the high-resolution image, data overlays, points of interests, and data streams can still be integrated using GIS technologies but only specific to the gridded image provided (Shea 2014; Reynolds and Smith 1994).

Regridding refers to the interpolation of one grid resolution image to a different grid resolution image, usually that of a sequence that depicts the immediate neighboring resolutions of a specific geographical region. Different methods such as temporal, vertical, or horizontal interpolation is used to combine the resolutions, but most commonly spatial (horizontal) interpolation is utilized (Shea 2014; Reynolds and Smith 1994). Depending on the type of analysis and data, appropriate interpolation techniques are required. To perform quantitative analysis on data points across many gridded resolutions, regretting across a common grid is required to avoid misleading numerical calculations among the data from different grid images. GIS applications and platforms provide many different interpolation techniques for regridding which allows for more accurate data analysis (Shea 2014; Reynolds and Smith 1994). This is a crucial tool that can ensure accuracy of very computationally large amounts of geographical data.

Monitoring and Measurement

GIS applications and systems can be configured to dynamically operate with real-time data streams from third-party data vendors or remote sensors that may provide climate-based or emissions-based information. A platform that can actively receive the data streams from the sensors and spatially visualize and overlay the data on a geographical plane relative to the sensor's logistical location can provide an automated monitoring system to detect potentially interesting climate or emissions patterns which can be practically interpreted depending on stakeholder interests (Rosenqvist et al. 2003; Reynolds and Smith 1994; Gibbs et al. 2007; Palmer Fry 2011). The monitoring aspect of GIS indicates the ability to process large amounts of data, store the data, and visualize the data in minimal amounts of time to provide insight to the stakeholder. Without this aspect or ability of a GIS platform or system, climate change analysis techniques would not benefit greatly from GIS technologies.

Reporting

The ability to retrieve information and analysis dynamically in an easy to interpret format is a key fundamental for a GIS system that may be developed for the purposes of climate analysis. The reporting mechanism allows the user of the system to gather important data and intelligence that could lead insight-driven decision. Both monitoring and reporting are crucial aspects of a GIS system designed for climate analysis due to the fact that reporting is based on the data derived from monitoring, and the insights from reporting are the primary output that analysis will be conducted on. Inaccuracies or inconsistencies in reporting may deem the GIS system obsolete, but accurate reporting could mean a substantial increase in productivity, efficiency, and progress in conducting relevant analysis and research on climate change (Rosenqvist et al. 2003; Reynolds and Smith 1994; Gibbs et al. 2007; Palmer Fry 2011).

Verification

The ability to monitor and report on different aspects of climate change based on statistical models or projections derived from historical data may not always accurately portray the actual observational data. Scientific analysis requires corroborated ground truth data to validate if the data models developed from historical data or data from a different region is statistically significant enough to be accurate. Verification is a critical factor in climate change mitigation policies due to the reliance on the ability to correctly determine climate change and emissions levels to properly incentivize global participants to achieve the common goal to degrade atmospheric temperature increases (Moore 2012). To achieve ground truth validations, climate change mitigation policies emphasize the requirement of approved sensors that can accurately verify the integrity of measurements taken at the point of production. This can be interpreted as remote sensors that are capable of measuring the "ground truth" data that is required in climate-based analysis scenarios. (Rosenqvist et al. 2003; Reynolds and Smith 1994; Gibbs et al. 2007; Palmer Fry 2011). GIS systems need to be scalable and adaptable to incorporate regulatory ground truth data or provide the appropriate information technology that meet the standards of climate mitigation policies.

Key Applications

Some of the aspects of climate change mitigation policies discussed offer financial instruments, incentives, and platforms for interested investors, impacted industrial stakeholders and participating nations to explore opportunities and strategies that can directly, indirectly, or residually impede the global temperature increase. Stakeholders who may decide to participate in the incentives offered by climate mitigation polices are aware that proper knowledge and analysis of climate change aspects that may be related to respective interests may provide a competitive edge for potential investment decisions (Kossoy and Guigon 2012). This section will explore some practical examples of Geographical Information Systems that perform climate science-related analysis and their application to different financial investment research.

Climate Finance

The term climate finance represents the financial mechanisms set in place by climate change mitigation policies, such as Kyoto Protocol and Copenhagen Accord, which allow for national, regional, and international parties to have access to financing channels specifically for climate change mitigation and adaptation projects and programs (Kossoy and Guigon 2012; Buchner et al. 2011). These projects and programs are developed based on achieving minimal carbon-based emissions footprints and resiliency to climate change through appropriate research and economic development. The term had been originally coined to refer to the obligations that developed countries committed to developing countries under the ratified UNFCCC policies; however, the term is now more synonymous with the all financial procedures and flows relating to climate change mitigation and adaptation projects and programs (Kossoy and Guigon 2012; Buchner et al. 2011). Financial funding can be provided from government budgets, domestic budgets, capital markets, and public and/or private sectors mediated through bilateral financial institutions, multilateral financial institutions, and development cooperation agencies or directly from the UNFCC itself via the Green Climate Fund, NGOs(nongovernmental organizations), and/or private sector. Investments decisions and strategies in renewable energy can potentially be considered climate finance if the renewable energy projects and programs qualify under the UNFCC guidelines (Kossoy and Guigon 2012; Buchner et al. 2011).

The financing projects and programs designed to mitigate or adapt the effects of climate change, such as the previously discussed Carbon Offset Programs, Clean Development Mechanisms, and Joint Implementation programs, have reached billions of dollars a year on average which is forecasted to grow into the trillions in the near future (Buchner et al. 2011; Moore 2012). To effectively monitor the funding needs, progress, success, and completion of projects and programs, the intermediaries of the climate finance framework rely on GIS-based tools and analysis to make informed data-driven decisions.

Carbon Finance

The UNFCCC stipulations of pollution and emissions control creates a realm in which carbon footprints and greenhouse gases are constrained to limit the potential increase in global climate change (Moore 2012). This constraint creates a commodity out of the amount of carbon-based or GHG emissions permitted for industrial and national interests (Raufer and Iyer 2012). Climate mitigation policy frameworks have promoted the investments in projects and programs that reduce the previously mentioned GHG emissions as well as provided a platform where the commodity of allowed emissions amounts are monetized into financial instruments that are tradable in a market-based cap and trade framework. The platform where the commoditized emissions allowances are exchanged is typically referred to the carbon market, while the overall concept of investing and trading these commodities can be represented by the term carbon finance. (Moore 2012; Raufer and Iyer 2012; Kossoy and Guigon 2012).

Carbon finance leverages the Kyoto Protocol's Clean Development Mechanisms and Joint Implementation framework to help facilitate the investments into emissions reductions projects to earn or trade emissions allowances or credits (Kossoy and Guigon 2012; Henríquez 2013). The World Bank facilitates carbon finance through its own carbon finance unit which purchases carbon credits or GHG emissions reductions generated from projects or programs in developing countries or transitioning economies to their fund contributors that employ their services, usually in the form of governments or companies with an interest in attaining or trading the carbon credits (Lewis 2010). The World Bank can achieve this by providing carbon funds and facilities which contribute to projects and programs that can yield carbon credits or GHG emissions reductions according to the Kyoto Protocol's Clean Development Mechanism and Joint Implementation frameworks (Lewis 2010; Henríquez 2013; Kossoy and Guigon 2012; Moore 2012). Essentially, the World Bank invests and supports projects and programs that qualify to earn carbon credits, which the World Bank can acquire and sell to interested parties through their carbon finance business (Lewis 2010; Henríquez 2013). Carbon credits are the official allowance of 1 metric ton of CO_2 or equivalent gases earned through approved projects or programs that progress the climate change mitigation agenda (Moore 2012).

The pricing of allowed carbon-based emissions is based on the limited supply and high demand for carbon credits (Litterman 2013; Henríquez 2013; Kossoy and Guigon 2012). To make informed investment decisions from the buyers and sellers' positions, proper financial analysis and careful investment research need to occur on the projects and programs that yield the carbon credits. Climate finance shares elements with carbon finance with respect to the dependence on GIS tools and analysis to determine if projects and programs properly qualify and succeed to earn carbon credits. Carbon finance, however, depends on both financial analysis and scientific research to make proper investment decisions (Litterman 2013; Henríquez 2013; Kossoy and Guigon 2012). GIS tools that combine both give stakeholders in carbon finance more insight when making critical decisions. Investment research can potentially incorporate GIS-based tools to understand estimates or forecasts of potential deficit or surplus in carbon emissions. GIS serves as an important investment research tool in the carbon finance domain because of the similarities to the commodities markets. Understanding the fundamentals of the commodity may help provide beneficial insight when investing in such a commodity. In the case of carbon finance, the commodity are the carbon credits or GHG emissions allowances yielded from climate mitigation projects or purchased from a carbon market at a market-competitive price.

Sustainability Risk Management

The awareness of the effects climate change may have on society and economy creates a legitimate business concern for investor and stakeholder confidence. Organizations which employ business strategies that do not take environmental risk factors, such as climate change, into consideration when planning, operating, or expanding may be adversely impacted by evolving climate change mitigation policies or effects of climate change. Organizations must solidify confidence with investors and stakeholders by engaging in business strategies that align operations and revenue goals with environmentally friendly policies. Global and national compliance regulations stemming from global climate change mitigation efforts call for renewable energy, environmentally friendly business practices, and sustainability initiatives. Organizations may not have a strategic initiative or outlook to align their business strategies with considerations for regulatory and environmental risks associated with climate change which can lead to lack of investment confidence and appeal (Zu 2013; Baumast 2013; Schmiedeknecht 2013). An example of this can be evidenced by organizational climate risk disclosures that are disseminated as public information for investors and stakeholders to review potential liabilities and assets of the respective business that can be impacted by environmental risk factors.

Sustainability Risk Management considers the optimal business strategy for an organization to achieve an effective and efficient balance between the prosperity of a business and its adherence to environmentally friendly policies. Traditional risk management and climate science techniques may be performed on business assets, interests, and liabilities to assess relative impacts to the organizational profit goals (Zu 2013; Baumast 2013). Sustainability and vulnerability assessments conducted in depth consider environmental risk factors such as floods, natural disasters, and climate change and how they may be detrimental to the business (Zu 2013; Baumast 2013; Schmiedeknecht 2013). They also consider adaptation strategies to achieve residency in the wake of such environmental risks for business continuity and prosperity which can be translated into long-term confidence for investors. To achieve such assessments, GIS tools and analysis can be employed to analyze environmental risk factors to business operations, supply chains, and other applicable business assets. Forecasting and simulation models of risk factors are considered as well as financial burdens that may be experienced by the impacted business (Zu 2013). After examination of each business process and potential environmental risks that may impact them are analyzed, strategies are developed to minimize the risks (Zu 2013). Integrated technologies utilizing GIS-based analysis and data management tools can be employed to conduct automated monitoring, auditing, and reporting on sustainability models and goals to achieve compliance. The identification of potential risks and issues impacting business interests early on can help the business maneuver its directional strategy to avoid costly regulatory failures or repetitional damage (Zu 2013; Schmiedeknecht 2013).

Sustainability Risk Management extends into the financial markets by allowing organizations that satisfy corporate sustainability assessments to be held in Sustainability Indices (Schmiedeknecht 2013). Sustainability indices represent an index of organizations considered to be socially responsible, environmentally friendly, and sustainable in the event of environmental risks. Investment firms that offer Sustainability Indices may market them as safer and resilient to climate change to potential investors who seek investment confidence relative to environmental risks (Schmiedeknecht 2013). Organizations who are able to reach Sustainability Indices may be considered a safer investment option compared to organizations that cannot achieve the same qualifications.

Future Directions

Climate change analysis and Geographical Information Systems share a relationship that will only evolve as the awareness and applications of climate change mitigation become more prevalent. GIS systems and tools are used to provide meaningful insight and intelligence for monitoring, reporting, and verification applications of climate change analysis. GIS technologies and systems may combine climate-related research and analysis data sources on geographical planes that can help perform traditional analytical techniques to yield data models that can be used to make strategic decisions. The continued emergence and demand for GIS and geospatial analysis skills in the climate science and investment research markets can be expected to grow as the relevance of climate-related applications, such as climate finance, carbon finance, and sustainability management, increases.

Important trends in climate change research, GIS, and financial applications are briefly discussed in the following sections.

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Mobile GIS Remote Sensor Networks

Mobile GIS remote sensor networks are considered an important topic in both climate research and GIS. To optimally and efficiently design, monitoring, reporting, and verification GIS systems that can potentially be incorporated into REDD+ projects and programs or other climate finance-funded projects are crucial to attain accurate data at the highest integrity standards (Samek et al. 2013; Rosenqvist et al. 2003; Patenaude et al. 2004). Much research is being conducted to optimize and propose equipment and techniques to achieve an economically and practically feasible approach to achieving GIS remote sensor networks that can potentially become a standardized method to collect and validate data such as emissions, carbon storage, carbon sequestration rates, air temperatures, and other climate change-related datapoint.

Data-Driven GIS Decision-Making Tools

GIS systems that can properly collect data from multiple data sources and conduct application-specific analysis on the said data with potential business logic are an area that climate change stakeholders are seeking to expand (Sizo et al. 2014; Benz et al. 2004; Ganguly et al. 2005). Climate-based financial and regulatory applications to automate business intelligent GIS systems that can perform dynamic analytical observations to yield insights to assist in decision-making scenarios can directly provide value-added service for climate change stakeholders. Automated sustainability assessments for organizations or GIS-based systems that can signal important investment research analysis are some of the many applications that data-driven geospatial analysis and technology is making available to the climate research and finance-based industries (Tomlinson 2007; Zu 2013).

Cross-References

- ▶ Financial Asset Analysis with Mobile GIS
- ▶ Climate Adaptation, Introduction
- ▶ Climate Extremes and Informing Adaptation
- ▶ Climate and Economic Stresses on the Water-Energy-Food Nexus
- ▶ Climate Hazards and Critical Infrastructures Resilience
- ▶ Climate Change and Developmental Economy
- ▶ Innovative tools and data sets for the geophysical sciences
- ▶ Climate Data Science: Informing Climate Adaptation with Big Data and Bigger Models
- ▶ GPS Data Processing for Scientific Studies of the Earth's Atmosphere and Near-Space Environment
- ▶ ArcGIS: General Purpose GIS Software System
- ▶ Data Models in Commercial GIS Systems
- ▶ Geosensor Networks, Formal Foundations

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