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# Digital Earth- Geographer's Vision & Challenge

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## Introduction

New technologies have always been important in advancing geographic understanding, but never have they been as thoroughly and rapidly transformative as at this stage of today. With the widespread introduction of computer technology, geography has entered another revolutionary phase in 21st century. Such a change has been brought about earlier by the Quantitative Revolution in 1950s, and now it is the Digital Revolution. Since geographers are directly concerned with analyzing the variable data on earth's surface, this has unwrapped vast areas for research and analysis. The modern techniques are opening up new avenues for geographers, and with their help it is possible to collect and interpret a variety of information. They are creating new and resurgent roles for geography in both society and in the university. The geographical tradition has gone through several phases, and Kuhn's ideas of scientific revolutions in the form of changing paradigms are clearly identifiable[1]. Presently a significant transition is going on from the strict positivist paradigm to more diverse approaches in our field. Today, the dynamic adoption of challenging new realms of information technologies and their spatial implications are visible to suggest the potential that geography has in the times to come. This new realm of information technology has been created by the Digital Revolution. The concept of 'Digital Earth" is a major outcome of this Revolution. It is the ambitious, exploratory and ground breaking concept. The Digital Earth's view offers geographers a new vision and challenge. Indeed, the entire Earth has now become digital, representing the 'datafied' counterpart of physical planet. Digital Earth is inherently becoming an intriguing notion for geographers. It is a vision that can motivate a wide range of interdisciplinary research and development activities. The present paper explores the Concept of Digital Earth with its key elements and the associated information and communication technologies; the bases, history and impact of Digital Revolution on Geography; major challenges ahead of geographers and the potential applications of Digital technology towards the geographical study of Earth's surface.

### *Digital Revolution*

Digital Revolution refers to the advancement of technology from analogue to digital. Implicitly, the term speaks of sweeping changes brought about by the digital technology during and after the latter half of 20th century. Analogous to the Agricultural Revolution and Industrial Revolution, the Digital Revolution marks the beginning of the Information Age. Central to this revolution is the Information and Communication Technologies (ICT) sector. The ICT sector represents a variety of devices and services built on scientific breakthroughs in computers, software design, photo-optics, circuit switching and satellites, among others. History has witnessed the search for ways to transmit information over distance greater than range of the human voice, at lower cost and with improved accuracy. Beginning with the advent of the written word and continuing with the invention of the printing press, information and communication technologies have changed in rapid succession, from the telegraph, radio, telephone, fax and most recently the Internet, Computer and Cellular Phone. The latter three are the most visible representation of ITC Revolution.

The development and advancement of digital technologies started with the fundamental idea of Internet. The Internet integrates telecommunications and allows access to all over the world in an interconnected web of machines, data and people. In addition, the technology has gone wireless; further decreasing the costs of being connected and potentially bringing more people into the digital world. By 1992, the World Wide Web had been introduced, and by 1996 the Internet became a normal part of most business and academic operations. By late 1990s, the Internet became a part of everyday life for a large number of people in the world. By referring to 'Internet', does mean not only the WWW (World Wide Web) but also email and news services. In fact, the Internet is expanding continuously at a logarithmic rate and this growth in near future will continue.[2] However, the Digital communication became economical for widespread adoption after invention of the Personal Computer and Cellular Phone.

Computers have been crucial in the history of geography and technology. The government, military and other organizations began making use of computer systems during 1950s and 1960s itself. This eventually led to the creation of the World Wide Web. During1980s, the computer became a familiar machine and by the end of the decade, it became a necessity.[3] From being a tool for geographers to collect, analyze, map and visualize data since 1950s, the computers have increasingly become an integral part of the geographers’ study by the end of 20th century. Computers now penetrate almost every aspect of our lives. It is under this broad scientific and societal milieu that geographers have entered the 21st century. No other technological innovation in human history has affected the practice of geography in such a profound way as the computer. Our traditional discipline has been radically transformed by Computers. Besides, the connection between Internet websites and mobile gadgets has also now become a standard in communication. Most of the world's population owns a mobile phone. Further, the innovation of tablet computers has far surpassed personal computers with the use of the Internet and the promise of cloud computing services.

The new area of geographical research sought its form during late 20th century. Much of the literature of that time was based either on evaluating mail-listings or conversation groups on the Internet dealing with one or two particular fields, or on assessing the possibilities for the future in the form of artificial intelligence, hyper-reality and fiction. By 2000s the Digital Revolution had begun to spread all over the world and became truly global. By 2012, over 2 billion people used the Internet, twice the number using it in 2007. Along with tablet computers and smart phones, Cloud computing had entered the mainstream by the early 2010s[4]. In late 1980s, for instance, less than 1% of the world's technologically stored information was in digital format, while it was 94% in 2007, with more than 99% by 2014. The year 2002 is estimated to be the year when it became possible to store more information in digital than in analogue format, marking the "beginning of the Digital Age".[5] It is estimated that the world's capacity to store information has increased from 2.6 exabytes in 1986, to some 5,000 exabytes (5 zettabytes) in 2014. The most recent development, in this direction, is geo-computation[6], the process of applying computing technology to geographical problems i.e. the ways in which new computational tools and methods are used in the depiction of spatial process. Although, some classic works[7] of the ongoing era have served as the philosophical and theoretical basis of the information society, still, it was not until the expansion of the Internet in the mid-1990s, when the analyses of experiences of networks, their meaning to users, their operability and other qualitative issues related to the communicational information systems started to gain more relevance to academic interest.[8]

## ***Impact***

The digital world has drastically transformed both the world of geography as an academic discipline and the geography of the world in which we live. Geographically disparate activities are more easily connected. Geographic separation no longer implies information deprivation. The traditional geography has been radically altered by the computer age since the last few decades. Computers have fundamentally changed not only how geographers study the world, but also what we study, as spaces and places, the natural and human landscapes, are constantly being refigured by computers. Computers have made writing, editing and publishing much faster and easier. Computers have extended geographers’ eyes (via remote sensing and air photos), their hands (via computer-assisted cartography), their mouth (via the World Wide Web and telephones), and their minds (via data processing and artificial intelligence). These extensions have greatly facilitated the acquisition, visualization, processing and communication of unprecedented amounts of geographic data. The impact of the digital revolution on Geography has, particularly, been large. Precisely, it can be seen in the form of emergence of new concepts in the discipline; accessibility to information; its globalization and outsourcing; new innovations in the fields and practice of discipline; creation of vastly more data sets; their eased coding and faster processing; and lastly, geography gaining a new disciplinary outlook.

The development and expansion of telecommunication networks have led to the emergence of new theoretical concepts of space as, e.g., the cyberspace and the 'shrinking world'. These indicate a societal transformation towards an 'information society'. The development of data-transaction speed and the enormous increase in users resulted in the Internet being known as the 'information superhighway', the 'electronic frontier' or the 'virtual land of expression'[9]. This is having an enormous impact on the academic interest of social and cultural scientists. Positive aspects of the Digital technology include greater interconnectedness, easier communication, and the exposure of information. This Digital information is compact, transportable and, therefore, more efficient to use. By way of conversion of technology from analogue into digital format, the information is more easily collected, stored, processed, accessed and communicated. There have been huge benefits to society from the digital revolution, especially in terms of the accessibility of information. Of great importance to the revolution is the ability to easily move the digital information between media, and to access or distribute it remotely. As a result of the widespread impact of Digital Revolution, various analogue technologies, as e.g. Mail (parcel),Telegram, Typewriter, Fax, Landline phone, etc. are fast disappearing.

The digital revolution radically changed the way the people interact. Without the World Wide Web (WWW), for example, globalization and outsourcing would not be nearly as feasible as they are today. Expanded powers of communication and information sharing, increased capabilities for existing technologies, and the advent of new technology brought with it many potential opportunities for exploitation. The digital revolution helped usher in a new age of mass surveillance, generating a range of new civil and human rights issues. The digital revolution made it possible to store and track facts, articles and statistics. These technological innovations have transformed traditional practice of data collection, presentation and analysis.

Computers have enriched the discipline of geography with the development of automated geography, GIS, and the virtual geography department. Computers and the computer-led information revolution have changed both scientific practices and many facets of human society in fundamental ways, as evidenced by the increasing emphasis of mapping and visualization as a discovery tool**[10]**. In addition, rapid innovations have fostered the development of specialized instruments and software tools that can greatly facilitate geographic research. For example, GPS, laptops, portable digital assistants (PDA), handheld computers, digital cameras, portable scanners and electronic data loggers. All raise the efficiency of field work as well as library retrieval. Computers have not simply automated the manual processes geographers were working on for years; they have also stimulated the new lines of inquiry, accelerated the quest for laws and theories, and addressed serious spatial issues in statistics, including the modifiable areal unit problem, spatial autocorrelation, and development of new spatial statistical techniques**[11]**. This has led to the emergence of new branches of geography, the most visible of all being quantitative geography, computer-assisted cartography, analytical cartography, remote sensing and GIS.**[12]** With the maturing of GIS technology and the further convergence among remote sensing, global positioning systems (GPS), and computer cartography, visualizing spatial data and mapmaking have been made much easier. The proliferation of GIS and the increasing use of geo-referenced data have made the broader social science community recognize the key role that space plays in human society.

The increasing use of computers has allowed geographers faster processing of larger sets of data. The increasing speed and capacity of computers allow and encourage the use of datasets that were simply unmanageable and tedious only two decades ago. Not only in physical geography (e.g., huge satellite imagery datasets, such as Landsat 1972) but also in human geography (very large census files), far more comprehensive datasets can be used and far more complex models can be run**[13]**. Besides, computers have vastly eased the coding of qualitative data (recorded interviews, answers to open-ended survey questions) through direct computer answering of surveys, data entry and analysis, and textual search.

The increasing use of computers has also contributed to the creation of vastly more data with better spatial and temporal resolutions. The digital processing of satellite imagery began as early as 1965 in the military, but has now exploded with the availability of high-quality, frequently updated images of most parts of the earth's surface. These images permit the analysis of change and processes, both short-term (weather, traffic) and long-term (physical and human land use), and also allow recognition of complex and previously hidden patterns revealing geological and historic processes. Also access to the vast amounts of spatial and non-spatial data has become unbelievably easy and convenient. With faster processing of more data comes the capacity to estimate ever more complex and distinct relationships and structures in data and to design and test far more comprehensive models of behaviour. It is now possible to execute notably intricate and useful simulations of the evolution of human landscapes (both past reconstructions and future scenario development). The most recent developments in geo-computation, especially in data mining and knowledge discovery techniques, have pushed the computing capabilities for spatial data to a new height**[14]**.

In reviewing the application history of computers in geography, it becomes apparent that computers not only helped make geography a more respected discipline among social scientists, but also that geographers, as they enter the 21st century, are beginning to play the leadership role among social scientists in addressing important social issues that have a spatial dimension. So dependent have we become so quickly on the web for information, and for data files, maps, and photos to download for our research and teaching, that we can scarcely remember that this has been possible for only a decade or so. Hundreds of maps, created by scores of agencies or organizations can be downloaded and printed. With the growth in routine use of the Internet (such as e-mail and web surfing) among geographers, and with more and more courses, journals, books, and data available on-line, a new geography department, Virtual Geography Department (VGD) emerged around 1997. The goal of the VGD is to produce and disseminate geographic knowledge and geography course materials. Computers are not simply tools, but are actually becoming part of the world we are trying to study using the very same tools. This new brave world, different from the physical and tangible world geographers studied for thousands of years, is virtual, digital and ephemeral. In this virtual world, everything that geographers study has become bits of information, which can be transmitted across the globe instantaneously.**[15]** Each one of us is not only an information processor, but also information processed. In other words, we have literally become digital individuals: our identity is more and more equated by digital information such as Social Security and Credit Card Numbers, multiple ID and PIN numbers. From these empirical studies and theoretical explanation, the computers have had and will continue to have enormous impact on society, on human behavior and interaction, on human settlement and the character of places, on the meaning of distance and of regions, and on the degree of spatial variation and inequality across the landscape. As a consequence, the content of geography has changed, for example, via the very concept of globalization, space-time compression, and space-time distantiation. The rapid, cheap worldwide transfer of messages, documents, data, and images has brought about yet another shrinking of distance and abetting of globalization in all its economic and cultural forms.

However, the most ambitious concept to exemplify the potential of computers both as tools and as reality is the concept of "Digital Earth." It is seen as a global strategic contributor to scientific and technological developments, and as a catalyst in finding solutions to international scientific and societal issues.[16]

### *Digital Earth: The Concept*

The term 'Digital Earth' was first used by Albert Arnold Gore, the American politician and environmentalist[17], in his speech prepared for the California Science Center in Los Angeles on January 31, 1998.[18] However, the origin of the idea can be traced back to Buckminster Fuller's Geoscope[19], a large spherical display to represent geographic phenomena. In Gore's speech, the digital earth is envisioned as a three-dimensional representation of the planet, into which are embedded vast quantities of geo-referenced data. The concept of Digital Earth was further explained as the use of digital technologies to model Earth systems, including cultural and social aspects represented by human societies living on the planet.[20] The model is a multi-dimensional, multi-scale, multi-temporal, and multi-layered information system. Digital Earth is the virtual representation of the Earth that is geo-referenced and connected to the world's digital knowledge archives.[21] Accordingly, Planet Earth appears to be wrapped in a gigantic mesh of fiber-optic cables and electromagnetic waves. The algorithmic (mathematical) regimes regulate the movement of goods and people around the world, generating, tracking and accumulating a mass of data so large that it is referred to as Earth's 'digital twin'[22]. The Digital Earth is not one, but it is multiply connected globes/infrastructures addressing the needs of different audiences: citizens, communities, policymakers, scientists and educationalists. Digital Earth is an integral part of other advanced technologies including: earth observation, geo-information systems, global positioning systems, communication networks, sensor webs, electromagnetic identifiers, virtual reality, grid computation, etc. Digital technologies have impacted not only the very process in which we create maps (through satellite imagery, GPS systems and user-adaptive cartography), but have become themselves a new variable in map-making. The world does not look like the maps familiar to us.

The Digital Earth looks like a globe, and proves to be a very powerful mechanism for visualization, and a metaphor for organizing the world's information. With the rapid development of internet, mobile network and Web technologies, significant improvements occurred in the collection of multisource spatial data. The availability of data providers is increasing as digital citizens are no longer limited to government agencies or professional companies. Ordinary civilian users can participate in and cooperate with others to maintain and update geographic information data. The idea that everyone can serve as a data collection sensor has become a reality. This new geographical era has been recognised as Neogeography[23]. It is a ubiquitous frame of reference as people and an increasing number of everyday objects online at all times. Concepts that embrace this new public data collection, such as volunteered geographic information (VGI), crowd sourcing geospatial data, and generalized geographic information, have been highlighted. Although the concepts vary, all of them emphasize the transformation of geospatial data acquisition. The bottlenecks in acquisition due to reliance on traditional, professional or government mapping have been uncorked using diversified and increasingly accurate active or passive data provided by the public. From a scientific point of view, the basic implication of Digital Earth includes two aspects. First, Digital Earth represents a huge data and information system that aggregates and presents data and information related to the Earth. In addition, Digital Earth is a virtual Earth system that can perform reconfigurable system simulations and decision support for complex geo-science processes and socioeconomic phenomena[25].

There are certain basic technologies that are needed for Digital Earth. They include, for instance, Computational Science, Modeling & Simulation, Satellite Imagery, Broadband networks, Interoperability and Metadata[25].Until the advent of computers, both experimental and theoretical ways of creating knowledge have been limited. Many of the phenomena that experimental scientists would like to study are too hard to observe - they may be too small or too large, too fast or too slow, occurring in a billionth of a second or over a billion years. Pure theory, on the other hand, cannot predict the outcomes of complex natural phenomena like thunderstorms or air flows over airplanes. But with high-speed computers as a new tool, we can simulate phenomena that are impossible to observe, and simultaneously better understand data from observations. In this way, computational science allows us to overcome the limitations of both experimental and theoretical science.

Modeling and simulation give us new insights into the data that we are collecting about our planet. The Digital Earth requires Mass Storage, i.e., storing quadrillions of bytes of information. The Satellite Imagery of Digital Earth provides a level of accuracy sufficient for detailed maps, and that was previously only available using aerial photography. This technology, originally developed in the U.S. intelligence community, is incredibly accurate. The data needed for a digital globe is maintained by thousands of different organizations, not in one monolithic database. The servers that are participating in the Digital Earth are connected by high-speed Broadband Networks. The Digital Earth also needs some level of interoperability, so that geographical information generated by one kind of application software can be read by another. The GIS industry addresses many of these issues. For imagery or other geo-referenced information to be helpful, it is necessary to know its name, location, author or source, date, data format, resolution, etc. This is Metadata, i.e., "data about data". Besides, further technological progress is needed to realize the full potential of the Digital Earth, especially in areas such as automatic interpretation of imagery, the fusion of data from multiple sources, and intelligent agents that could find and link information on the Web about a particular spot on the planet.

Several key elements of the Digital Earth may be summarized[26] as follows:

1. The Digital Earth is not one, but it is multiply connected globes/infrastructures addressing the needs of different audiences: citizens, communities, policymakers, scientists, educationalists;
2. It is problem oriented and is transparent on the impacts of technologies on the environment, health, societal benefit areas;
3. It allows search through time and space to find similar/analogue situations with real time data from both sensors and humans (different from what existing GIS can do, and different from adding analytical functions to a virtual globe);
4. It asks questions about change, identification of anomalies in space in both human and environmental domains;
5. It enables access to data, information, services, and models as well as scenarios and forecasts: from simple queries to complex analyses across the environmental and social domains;
6. It supports the visualization of abstract concepts and data types (e.g., low income, poor health, and semantics);
7. It is based on open access, and participation across multiple technological platforms, and media (e.g., text, voice and multi-media); and
8. It is engaging, interactive, exploratory, and a laboratory for learning and for multidisciplinary education and science.

Digital Earth is meant to help humankind take advantage of the geo-referenced information on physical and social environments, linked to an interconnected web of digital libraries. It is envisaged as a common platform to support national and international cooperation for global sustainable development, economic growth and social well-being. Digital Earth is seen as a global strategic contributor to scientific and technological developments, and as a catalyst in finding solutions to international scientific and societal issues. It is believed to play a strategic and sustainable role in addressing such challenges to human society as natural resource depletion, food and water insecurity, energy shortages, environmental degradation, natural disasters response, population explosion, and, in particular, global climate change. Data acquisition, organization, analysis and application on these variables - all reflect the importance and necessity of effectively handling massive volumes of scientific data. It not only visualizes the present physical features of the Earth but also the past through historical data, and the future based on the outcome of integrated models. Digital Earth is dynamic and interactive exploiting the full range of information flows from sensors and people. It synthesizes heterogeneous information and provides metrics of quality and trust of both data inputs and outputs. It is more participative as people have a greater say not only in providing data but also in interpreting the data and shaping the construction of scientific 'evidence', and arguing the pros and cons of different policy choices. As a result, it improves our collective understanding of how the Earth works, and how it responds to both physical and social interventions. It is not just about space and spatial relations but also about place, culture and identity, spanning the physical and virtual space. It, thus, emphasizes the analysis of networks and flows, and relationships between places (e.g., cultural influences, links established through migratory flows or history) in addition to the traditional spatial analysis.

### *Evolution & Diffusion*

The diffusion of evolutionary concept of Digital Earth has been very fast over the years. Along with the social changes, technology advances have been incrementally achieved, resulting in the evolution of

Digital Earth. As stated earlier, the concept of Digital Earth describes the idea of a three-dimensional digital replica of the planet earth that can allow real-time visualization and manipulation of complex data layers at both global and local scale. The development of a number of prototype models led to its eventual development. Based on command-and-control technologies, there are several virtual globe platforms, or geobrowsers, with associated visualization applications. Among them, the three major categories are location-based commercial platforms, science platforms based on Earth system sciences, and public platforms oriented towards regional sustainable development and decision support[27].

Evolutionary threads of the Concept of Digital Earth can be traced to 1970s when the human being first stepped on the moon’s surface, and the space and information age was launched with the Landsat series of Earth observation satellites. Beginning in 1972, Landsat data kick started the big-data epoch by capturing imagery of the whole Earth’s surface every two weeks. From these space-age origins, a multitude of technologies have developed to address data storage, pre-processing, classification, interpretation, analysis, integration with computational models, and visualization in digital image processing workflows. Digital image processing has spread across science, medical, computer, gaming, and entertainment fields, creating multitudes of new industries. With the booming development of Earth observation, massive amounts of digital data about Earth’s surface and near-surface have been collected from an ever-growing constellation of various satellites and sensors.

Although, the technological developments that support the current Digital Earth framework can be tracked down to the United Nations as well as the nations like USA, China and Japan, the philosophical foundations for Digital Earth are more closely aligned with the increased awareness of global changes and the need to better understand the concepts of sustainability for the planet's survival. At the roots, as already mentioned, lie the visionaries such as Buckminster Fuller who proposed development of a Gyroscope half a century ago, analogous to a microscope to examine and improve our understanding of the planet Earth. However, the key historic and multidisciplinary foundations of the Concept were foresightedly articulated and represented at the first International Symposium on Digital Earth (ISDE) held at Beijing in China in 1999[28]. The Symposium was sponsored by the Chinese government. The inaugural of ISDE in Beijing, provided a venue for the extensive international support for implementing the Gore Digital Earth vision with the Chinese government's full backing. In China, Digital Earth became a metaphor for modernization and automation with computers. More than one thousand scientists, engineers, educators and governors from nearly 40 countries worldwide attended the Symposium. Since then, many countries’ governments and institutes have produced Digital Earth platforms for specific research purposes. For instance, the Chinese Academy of Sciences started research on a Digital Earth Prototype System in 1999 and released the Digital Earth Science Platform (DESP/CAS)[29]. Responding to the vision for Digital Earth, the US government established a NASA-led Interagency Digital Earth Working Group in 1999[30]. The attendees approved a milestone document for the movement, the *1999 Beijing Declaration on Digital Earth*. This symposium laid the foundation for the development of Digital Earth at the global scale, and kicked off the worldwide responses to the Digital Earth initiative. Japan, led by Keio University and Japan Aerospace Exploration Agency (JAXA), has also played a prominent international role in Digital Earth helping to create the Digital Asia Network. The United Nations Environment Program (UNEP) in 2000 advanced the Digital Earth to enhance decision-makers' access to information. UNEP promoted use of web-based geospatial technologies with the ability to access the world's environmental information, in association with economic and social policy issues.

During the symposium, an International Steering Committee of the International Symposium on Digital Earth was established to organize subsequent symposia in the coming years. In 2006, International Society for Digital Earth (ISDE), was formally established, as the non-profit international scientific organization, with the secretariat hosted by the Chinese Academy of Sciences, to coordinate academic exchange, education, science and technology innovation, and to promote international collaboration towards Digital Earth. Important to the professional standing of the ISDE is the addition of an international peer-reviewed academic journal, the *International Journal of Digital Earth* (IJDE), launched in 2008. The highly rated journal is published jointly by the ISDE and the Taylor & Francis Group. IJDE concerns with the science and technology of Digital Earth and its applications in all major disciplines. Further, the ISDE is also involved in promotion of academic exchange, science and technology innovation, education, and international collaboration. Besides, there have been several ISDE symposia and Digital Earth Summits, proceedings for many of them being available. The Digital Earth initiative fits within many global organizations’ missions through sharing knowledge and ideas about the planet Earth and seeking global benefits using Digital Earth technology. In 2009, the ISDE joined the Group on Earth Observations (GEO), the world’s largest intergovernmental organization on using geospatial data. The ISDE’s membership in the GEO guarantees organizational and scientific harmonization with all major international communities. The ISDE has also established partnerships with the Committee on Data for Science and Technology (CODATA), the International Eurasian Academy of Sciences, the Global Spatial Data Infrastructure Association, and the

African Association of Remote Sensing of the Environment. In 2017, the ISDE was recognized as a member of the International Council for Science (ICSU, now is the International Science Council). In August 2019, ISDE became a member of the United Nations Committee of Experts on Global Geospatial Information Management—Geospatial Societies (UN-GGIM GS). The ISDE is now widely recognized globally as a leadership organization in geospatial information science research.

In addition to the ISDE, other examples of Digital Earth relevant organizations also include :(1) The World Council for Science, which is the most active body supporting the professional development of multi-disciplinary scientists and the promotion of science to sustain and progress humanity; and (2) The Group for Earth Observations (GEO), which is already collaborating with the ISDE, United Nations agencies, and natural environmental systems organizations (e.g. the World Meteorological Organization) to advance the implementation of Digital Earth vision. Besides, the UN Program on Global Geospatial Information Management (GGIM) aims at playing a leading role in setting the agenda for the development of global geospatial information and to promote its use to address key global challenges. It provides a forum to liaise and coordinate among Member States, and between Member States and international organizations. Other pertinent organizations, from the potential user side, are, for example, the International Society of City and Regional Planners, the World Business Council for Sustainable Development, the World Federation of Engineering Organizations and the Institute of Electrical and Electronics Engineers.

On the similar lines, as above, has been established the Australian Geoscience Data Cube (AGDC). It aims to realize the full potential of Earth observation data holdings by addressing the big data challenges of volume, velocity, and variety that otherwise limit the usefulness of Earth observation data. The AGDC is a collaborative initiative of Geoscience Australia, the National Computational Infrastructure (NCI), and the Australian Commonwealth Scientific Industrial Research Organisation (CSIRO). The AGDC was developed over several years as researchers sought to maximize the impact of Land surface image archives from Australia’s first participation in the Landsat program in 1979.There have been several versions of AGDC, and core components of the AGDC are (1) data preparation, including geometric and radiometric corrections to Earth observation data to produce standardized surface reflectance measurements that support time-series analysis, and collection management systems that track the provenance of each data cube product and formalize reprocessing decisions; (2) the software environment used to manage and interact with the data; and (3) the supporting high-performance computing environment provided by the Australian National Computational Infrastructure (NCI)[31]. The AGDC vision is of a ‘Digital Earth’ composed of observations of the Earth’s oceans, surface and subsurface taken through space and time and stored in a high-performance computing environment[32]. A fully developed AGDC would allow for governments, scientists and the public to monitor, analyse and project the state of the Earth and will realize the full value of large Earth observation datasets by allowing for rapid and repeatable continental-scale analyses of Earth properties through space and time.

Following the 1999 symposium, a symposium has been held every two years at different locations around the world. In addition, since 2006, Digital Earth summits have been added to the biannual symposia schedule to focus on specific academic themes. The *Beijing Declaration on Digital Earth* is recognized for its role in promulgating the series of International Symposia on Digital Earth to promote understanding of the impacts of DE technology and applications on behalf of humankind. Combinations of industrial, academic, and government organizations have rapidly advanced the technological components necessary for implementing the DE vision. Commercial leaders such as Google have accelerated the influence of DE for large segments of society. The launch of the Google Earth service in 2005, and its adoption by both scientific and educational communities, has been part of a wider expansion and development of geospatial applications and data.

Significant progress towards Digital Earth has been achieved over the last decade[33] including work in the field of, for instance, Spatial Data Infrastructure (SDI)[34], Geobrowsers[35], Sensor networks and Volunteered Geographic Information (VGI). The Volunteered Geographic Information refers to the rapidly growing volume of social and scientific geo-referenced user-generated content being made available on the Web by both expert and non-expert individuals and groups. This phenomenon is seen as an emerging Geoweb that provides Application Programming Interfaces (API's) to software developers and increasingly user-friendly web mapping software to both scientists and the public at large. Besides, Several International communities and Organisations have been formed and are active in this direction. The number of Spatial Data Infrastructures has grown steadily since the early 1990s. The scientific use of geo-browser virtual globes such as Google Earth, NASA's World Wind, and ESRI's Arc GIS Explorer has also grown significantly. Large scale networks of geosensors[36] have been in place for many years, measuring Earth surface; its hydrological and atmospheric phenomena. The advent of the Internet led to a large expansion of such networks.[37]

The emergence of early geobrowsers has been supported by geospatial tessellation engines operated within desktop computers using 3D technology. Based on 3D Earth geographic teaching software, was developed an ‘Atlas 2000’ by Microsoft, an original prototype of the Earth system in 2001, which integrated large-scale remote sensing imagery and key point datasets into a global 3D model. Following that ArcGIS Explorer of ESRI (Environmental Systems Research Institute) and Google Earth were launched in 2005. When integrated, these Digital Earth systems allow for querying, measurement, analysis, and location services based on massive geospatial data[38]. Since then, a number of virtual globes have been produced, including World Wind, Skyline Globe, Geo-Globe, and Bing Maps 3D. A federally funded research and development center managed for NASA, The Jet Propulsion Laboratory, created Eyes on the Earth to visualize in situ data from a number of NASA's Earth orbiting spacecraft. The Australian government explored Blue Link and Glass Earth to observe and simulate the ocean and explore the Australian continent's surface and its geological processes. A consortium of Japanese institutes developed the Earth Simulator to support environmental change research. Pioneering groups in government, industry, and academia have cultivated this fertile futuristic conceptual model with technological incubation and exploratory applications. An array of space-age developments in computers, the internet and communications, Earth observation satellites, and spatially oriented applications sparked an innovative discipline.

Digital Earth has evolved into a new connotation of 'big Earth data'[39]. Big Earth data incorporates a long list of powerful tools requisite to understanding and explaining the Earth system and to investigating sustainable global development. It focuses on the synthesis and systematic observation of Earth, as well as data-intensive methods for studying Earth system models with the goal of increasing knowledge discovery. Big Earth data can be expected to promote the Digital Earth vision by connecting multiple satellites and geographical information centres that rely on national spatial infrastructures and high-speed internet to complete the acquisition, transmission, storage, processing, analysis, and distribution of spatial data. Entering the big data era, national and regional governments responded by releasing relevant strategies accordingly. For example, in 2011 the European Commission announced a statement on "Open Data: An Engine for Innovation, Growth and Transparent Governance". In 2012, the United States released the "Big Data Research and Development Initiative" to enhance the capability of knowledge discovery through big data. Australia published "The Australian Public Service Big Data Strategy" in 2013. Subsequently, the Chinese government began emphasizing big data as one of the strategic resources of social development in 2013 and issued the "The Action Plan for Promoting Big Data Development" in 2015, including a proposal for "Developing Science Big Data". In 2012, the UN Global Pulse published "Big Data for Development: Opportunities and Challenges" to promote the significant role of big data in responding to climate changes. The International Council for Science (joined in 2017 with the International Social Science Council to form the International Sciences Council) published their "Strategic Plan 2012–2017", which emphasized the importance of data management in new knowledge discovery. Big data has created a new computational perspective in the use of continuously collected data from various sources to explore trends in large volumes of data and to better understand world dynamics. Such advances bring great opportunities for Digital Earth to play its visionary role in integrating the massive amount of multi-dimensional, multi-temporal, and multi-resolution geospatial data as well as socio-economic data in a framework for comprehensive analysis and application systems about the Earth.

Today Earth observation has become a major part of many countries' environmental and defence programs since the final decades of the last century. Nations were influenced by the Planetary Mission of NASA's Earth Observation Program. A new generation of space-Earth observation continues and has been extended to incorporate observations of the land, atmosphere, ocean, ecosystem processes, water and energy cycles, and solid Earth. One example of such Program is The Global Monitoring for Environment and Security (GMES) program, jointly established by the European Space Agency (ESA) and the European Commission in 2003. Earth observations have expanded rapidly around the globe. Bringing Earth observation down to Earth with an ever-increasing number of Earth observation satellites with increasing spatial, temporal and spectral resolutions represents a critical data input to the Digital Earth concept. Dozens of countries such as Australia, China, Japan, Singapore, South Africa, and the European Commission have generated their own Digital Earth-related programs. There has been important progress in these efforts, such as Digital Earth Australia established by the Australia federal government in 2017, the Geoscience Australia Data Cube (supported by the Commonwealth Scientific and Industrial Research Organization, the National Computational Infrastructure, and the National Collaborative Research Infrastructure Strategy of Australia), Digital China promoted by the Chinese government, the Key Laboratory of Digital Earth Sciences established by the Chinese Academy of Sciences, and the IDEAS (International Digital Earth Applied Science Research Centre) at Chubu University in Japan, as well as those at several universities with Digital Earth departments or laboratories (e.g., Austria and Malaysia). In 2011, a group of experts from the International Society for Digital Earth gathered at the "Digital Earth Vision to 2020" workshop in Beijing to discuss the developing trends of Digital Earth. This workshop discussed the achievements of Al Gore's first generation of the Digital Earth vision. It was indicated that the existing generation of Digital Earth (or Virtual Globes) represented great progress in Gore's vision.

Digital Earth theories and relevant technologies have flourished across a range of disciplines and applications worldwide[40]. This momentous turn in the histories of cartography, meteorology, and geography was made feasible by the confluence of enabling information technologies in computational science, mass storage, satellite imagery, broadband networks, interoperability, metadata, and unprecedented 'virtual reality' technologies. Powered by advances in semiconductor devices networked to telecoms, navigation, and Earth observation satellites, a new era of spatially enabled technologies transformed and fused multiple disciplines in the 21st century. As a system of interconnected systems, Digital Earth is fully empowered with multiple sources of geospatial information, a 3D representation platform of the Earth, and a user interface, and acts as the framework that combines these domains. As stated in the *Beijing Declaration on Digital Earth*, Digital Earth is an integral part of other advanced technologies including: Earth observation, geo-information systems, global positioning systems, communication networks, sensor webs, electromagnetic identifiers, virtual reality, grid computation, etc.

The next generation of Digital Earth is not projected to be a single system and will likely be multiple interconnected infrastructures based on professional standards for open access and horizontal participation across multiple technological platforms. Client-friendly and customized platforms will drive the growth of different audiences. It is believed that Digital Earth is a powerful metaphor for accessing the multiscale 3D representation of the globe. The growth of Digital Earth is predicated in part on emphasizing its usefulness to the public. Continued development and evolution of internet bandwidth and improved visualization techniques can be expected to maintain the growth of Digital Earth applications. Equally important for public applications are social developments and the widespread adoption of social networks, which serve as key ways to communicate and turn citizens into force multipliers as providers of information. 'Digital' refers to more than the electronic format of the data in bits and bytes or the automated workflow used to manage the data. The Digital Era encompasses the much wider and greater societal and technological transformations facing humans. "Digital Earth is the inevitable outcome of the space era in the history of information society development". Digital Earth captures this phenomenal extension to harness the 'digital' world in which we live. [41]

### *Digital Earth: The Challenges*

The vision of 'Digital Earth', as articulated by Al Gore, was trusted to make it possible to find, visualize and make sense of vast amounts of geo-referenced information on physical and social environments. Such a system was to allow users to navigate through space and time, accessing historical data as well as future predictions, and to support its use by scientists, policy-makers and common masses alike.[42] At the time, this vision of Digital Earth seemed almost impossible to achieve given the requirements it implied about access to computer-processing cycles, broadband internet, interoperability of systems and above all data organization, storage and retrieval. But now geo-browsing has brought many of these elements of Digital Earth to the fingertips of hundreds of millions of people worldwide. Digital Earth is regarded as an approach for addressing the social, economic, cultural, institutional, scientific, educational, and technical challenges, allowing humankind to visualize the Earth, and all places within it, to access information about it and to understand and influence the social, economic and environmental issues that affect their lives in their neighbourhoods, their nations and the planet Earth[43]. Solutions to challenging problems remain indefinable under conventional governance. In this dynamic environment, better methods for organizing vast data and managing human affairs are sought at all organizational levels. While not a panacea, Digital Earth has been regarded as the most effective approach, organizing metaphor, or model, to turn raw and disaggregated data into understandable, visualized information to gain knowledge about the Earth and human influence. Consequently, it can aid in the sustainable development of all countries and regions[44].

The increasing intangibility in geography, as evidenced by the emerging digital individuals, virtual cities, and digital earth itself, has raised many fundamental scientific, socioeconomic, and ethical questions that need further investigation. A number of reports have been published in recent years that try to identify the key issues and challenges to be faced in the coming years[45]. From these documents, there seems to be a large degree of consensus that at the global level there would be an increasing shift in economic wealth and power, resulting in a multi-polar world, and new challenges for governance and academics. Increased world population combined with increased economic wealth will put major pressures on strategic resources: energy, food and water. As a consequence, there will be continued (and increased) disparities within countries and across continents, e.g., potential doubling of people with limited access to fresh food and water, and potential for conflicts, particularly in the developing countries. Western countries will not only face their specific challenges related to energy and the environment but will also be confronted with particular tensions in balancing competitiveness, cohesion, ageing populations and immigration. Focusing specifically on the environment, there is a broad consensus that climate change, loss of biodiversity, water scarcity and the impact of chemicals and carbon emissions on air quality and public health will continue to be major issues in the next few decades.

Embedding environmental perspectives into social and economic policy requires a more holistic and cross-sectoral way of working, strengthening local to global interactions and improving scientific understanding. In this respect, greater transparency about assumptions, shared access to data and better communication of scientific findings become critical to gathering and retaining the support of society and policy-makers. From these scenarios, the requirements for Digital Earth are to provide a framework for shared global access to information supporting the sustainable use and equitable distribution of scarce resources across regions and generations. Such a framework needs to support scientific research, but also public participation in science and in the strategic choices affecting our planet. Digital Earth challenges our state of knowledge about the planet, not only in terms of raw data, but also in terms of data access and the ability to communicate data through visualization. Moreover, it challenges our understanding of process in the invitation to model, simulate, and predict, since the concept is not limited to static portrayal. The ability of the Digital Earth technology was envisioned as requisite to assist nations, organizations, and individual citizens in addressing the problems humans are facing in the 21st century. These challenges for all nations require the comprehensive scope and analytical capacity of Digital Earth technology. If successful, it is believed to have broad societal and commercial benefits in areas such as education, decision-making for a sustainable future, land-use planning, agricultural, and crisis management. The Digital Earth project allows us to respond to manmade or natural disasters - or to collaborate on the long-term environmental challenges we face. Thus, Digital Earth plays “a strategic and sustainable role in addressing such challenges to human society as natural resource depletion, food and water insecurity, energy shortages, environmental degradation, natural disasters response, population explosion, and, in particular, global climate change”[46]. Digital Earth also serves as a basis of new research interest in network geography that originally derives from the quantitative era of human geography.

The academic literature on Digital Earth has been growing steadily in recent years. Reviewing the literature on Digital Earth, it is possible to discern a few major streams of challenges. Some of the most fundamental developments challenging geographers at the beginning of the twenty-first century are discussed here, as for example, the Digital Earth as - a research challenge, an information system, an organizing metaphor, a strategic infrastructure, a geographic study of Noosphere, a platform for Global Sustainability Research, a diverse technological field of geographic study, a basis of new research interest in network geography and a recognizer of the role of multiple stakeholders.

*Digital Earth as a research challenge:*

In this stream are outlined research issues that arise from the vision of Gore speech, viz. in the areas of data structures, indexing schemes, data integration, semantic integration (the process of interrelating information from diverse sources), cartographic technique, geo-visualization and institutional arrangements. Besides, considering the major developments that have taken place since Gore’s speech, there have also been added certain new topics that address the opportunities of sensor webs in providing dynamic data flows on the state and responses of the environment[47].

It is being argued that at the present moment there are three broad dominating perspectives of research analyzing relations between information technology, space and place[48]. The first is the perspective of substitution and transcendence. The core of this approach is a utopia that areal territoriality, spaces and places and their dynamic production could be substituted and replaced by using new technological innovations. It is argued that space itself has become unnecessary, and that we all are able to live in a 'spaceless city' in which the integrated broadband systems are the highways of knowledge. The second perspective is defined as the tendency of ‘the parallel social production of geographical space and electronic space’. This approach recognizes the complexity of societal evolution and treats IT as a part of that evolution. Therefore, technology and society are forming a dualistic relationship through which different new advancements, spaces, places and actions are produced and reproduced. Indeed, informational cyberspace and real-world space are not separate and competing entities, but a simultaneously growing and evolving unit - the sphere and the scene of human existence. Finally**,** the last discourse of writings is the recombination approach and the widely used idea of actor-networks. The actor-network theory has been comprehensively used and discussed in academic forums. The central idea is to acknowledge the contextual nature of human-computer relations. The focus is on assessing the diversity of human interactions and their differences through different sets of human actor-technology recombination. The emphasis is on the creativity of humans to consolidate certain kinds of relationships in different spaces with different persons. Therefore, technology is evolving into specific parts of interactions, and the boundaries between the human actor and the machine have become blurred.

*Digital Earth as an information system:*

Digital Earth is an integrated set of components for collecting, storing, and processing data and for providing information and knowledge about Earth. This perspective comes close to the systems approach, as it considers Digital Earth as a system: ‘a comprehensive, distributed geographic information and knowledge organization system’ which is based on participant systems that adhere to an agreed set of protocols and standards for data models, data formats and metadata, allowing it to function as a contributing node in a single, virtual computing system.[49]

Correlated with many of sciences dealing with the surface and near-surface of Earth, Digital Earth has been envisioned as an initiative for harnessing the Earth’s data and information resources[54]. It can serve as a powerful tool to map, monitor, measure, and forecast natural and human activities. There is an unparalleled opportunity to turn a flood of raw data into understandable information about our society and out planet. This data include a variety of economic, social, and demographic information. A Digital Earth can provide a mechanism for users to navigate and search for geospatial information - and for producers to publish it. The Digital Earth is composed of both the "user interface" - a browsable, 3D version of the planet available at various levels of resolution, a rapidly growing universe of networked geospatial information, and the mechanisms for integrating and displaying information from multiple sources. The Digital Earth represents a new wave of technological innovation that allows us to capture, store, process and display an unprecedented amount of information about our planet and a wide variety of environmental and cultural phenomena. Much of this information is "geo-referenced" - that is, it refers to some specific place on the Earth’s surface. Now we have more information than we know what to do with, and there is an insatiable hunger for knowledge.

*Digital Earth as an organizing metaphor:*

Digital Earth is interesting because of its implications for the organization of information. The tools we have most commonly used to interact with data, such as the "desktop metaphor" are not really suited to this new challenge. Digital Earth is a much better metaphor to organize, search and retrieve the information necessary to understand the Earth phenomena than the desktops. The prevailing metaphor of user interface design is the office or desktop, with its filing cabinets, clipboards, wastepaper bins and so on[51]. Many prototype digital libraries employ the library metaphor, with its stacks and card catalogs. But Digital Earth suggests a much more powerful and compelling metaphor for the organization of geographic information, by portraying its existence on a rendering of the surface of the Earth. This idea can be seen in limited form in many current products and services, including Microsoft’s Encarta Atlas. What has changed most since 2011 is that speech has become the main method of interaction with Digital Earth, replacing text on tiny keyboards.

*Digital Earth as a strategic infrastructure*

Advocated by Guanhua in china, it is a perspective focusing in particular on Digital Earth not only for sustainable development and management of natural resources but also as a catalyst for leapfrogging development in science and technology[52]. Guanhua focuses, in particular, on DE for sustainable development and management of natural resources but also as a catalyst for leap-frogging development in science and technology. The strategic nature of Digital Earth is also strongly put forward as strategic as ‘the atom bomb, hydrogen bomb, and artificial satellites’[53.] It is argued that that ‘possessing DE is equivalent to taking the highest control point in modern society’[54]. A similar, yet more tactical view of DE focuses on the concept of DE as a ‘moonshot’ that can motivate and mobilize cutting-edge research.[55]

*Digital Earth as a geographic study of Noosphere.*

At a much deeper level, Digital Earth may be regarded as a materialization of what has been called the ‘Noosphere’, dominated by flows of digital information.[56] The study on the geography of Noosphere offers a new challenge for geographers in the 21st century[57]. Representing an evolutionary theory, the Noosphere has been defined as the new state of the biosphere[58]. It represents the highest stage of bio-spheric development, its defining factor being the development of humankind's rational activities. The conceptions of the noosphere share the common thesis that together human reason and the scientific thought has and will continue to create the next evolutionary geological layer. This geological layer is part of the evolutionary chain.[59] It is argued that human activity becomes a geological power and that the manner by which it is directed can influence the environment. The noosphere is as much part of nature as the barysphere, lithosphere, hydrosphere, atmosphere, and biosphere. As a result, one sees the "social phenomenon [as] the culmination of and not the attenuation of the biological phenomenon."[60] These social phenomena are part of the noosphere and include, for example, legal, educational, religious, research, industrial and technological systems. In this sense, the noosphere emerges through and is constituted by the interaction of human minds. The noosphere thus grows in step with the organization of the human mass in relation to itself as it populates the earth. It is argued that the noosphere evolves towards ever greater personalization, individuation and unification of its elements. Finally, the complexification of human cultures, particularly language, facilitated a quickening of evolution in which cultural evolution occurs more rapidly than biological evolution. Recent understanding of human ecosystems and of human impact on the biosphere have led to a link between the notion of sustainability with the "co-evolution"[61] and harmonization of cultural and biological evolution.

### *Digital Earth as a platform for Global Sustainability Research*

Digital Earth is closely interrelated with the global sustainable development challenges and processes, as evidenced through national Earth observation agencies’ efforts to connect and integrate big Earth data into the application of many social and environmental programs. Over the coming years the global scientific community needs to take on the challenge of delivering to society the knowledge and information necessary to assess the risks humanity is facing from global change and to understand how society can effectively mitigate dangerous changes and cope with the change that we cannot manage. This field has been referred to as ‘global sustainability research”.[62] The International Council for Science (ICSU) has identified five scientific priorities, or Grand Challenges, in global sustainability research. These Grand Challenges, for instance, include,:(i) Developing the observation systems needed to manage global and regional environmental change;(ii) Improving the usefulness of forecasts of future environmental conditions and their consequences for people;(iii) Recognizing key thresholds or non-linear changes to improve our ability to anticipate, recognize, avoid and adapt to abrupt global environmental change; (iv) Determining what institutional, economic and behavioural responses can enable effective steps towards global sustainability; and (v) Encouraging innovation (coupled with sound mechanisms for evaluation) in developing technological, policy and social responses to achieve global sustainability. ICSU also argued that tackling these grand challenges requires a stronger involvement and greater integration of the social sciences, health sciences, engineering and humanities, along with the natural sciences. In other words, there is a strong need to move from disciplinary research to multi-disciplinary research. Moreover, an effective response to global environmental change requires not only better science but also more focused collective action by all stakeholders. This entails two key priorities, viz Communicating science more effectively to close the gap with citizens and policy-makers, and Engaging the public in the scientific process such as helping monitoring the environment, reporting observed and perceived changes and impacts for example via social networks. Digital Earth is believed to include all of the above to meet the challenge of global sustainability research. Besides, it is also expected to exploit the new opportunities (not foreseen at the time of the Al Gore speech) offered by the massive deployment of sensors, and the rise of social networks to develop a truly participative and a near-to-real time nervous system for planet Earth. Achieving sustainable development presents all countries with a set of significant development challenges.[63].

### *Digital Earth as a diverse technological field of Geographical study*

The innovative ways to organize and present data from rapid advancements in hardware, software and data capture and processing are benefitting today’s users of the geobrowsers, Google Earth (and commercial alternatives as Bing and Digital Globe). To be a geographer and to study anything related to 'information' systems leads directly to the idea of combining the two into geographical information systems – GIS[64]. Therefore, the notion of separating three main genres is of the utmost importance if this area of research is to be understood. These three genres are:(1) GIS and the idea of mapping, (2) traditional approaches in human geography, and (3) new areas of cultural geography and the virtual embodiment of the human actor. These different approaches described here merge together into a diverse genre of geographical information technology analyses.

The importance of technology is measured directly through the analytical capacity that provides the power to handle massive amount of data. The dynamic possibility of real-time data updates with a large number of variables creates the instrumental utility that information technology has. Here, GIS is more popularly used in geographical analysis among both, the human and physical geographers. The human geographers have especially used GIS in urban planning projects or in studying the spatial dispersion of diseases for example,[65], but evidently, in geographical analyses the greatest impact of GIS is on physical geography.

The traditional research branches of human geography have also begun to expand their own areas of research to areas provided through technological advancements. Three large groups of research interests may be delineated in this context[66]. (1) Firstly**,** there is the research concerning globalization and financial concentration. This branch derives from the notion that economic geography continues to play a major role in the analysis of networks. Studies in this area are strongly connected to the expansion of the world market and to analyses of monetary flows. Innovations spread or diffuse with great rapidity under current conditions. Indeed, one of the most significant sets of innovations is in the sphere of communications, which itself facilitates such technological diffusion. Technology is, without a doubt, one of the most important contributory factors underlying the internationalization and globalization of economic activity."[67]. Analysis in this area is usually done by evaluating the directions and volumes of transactions. The economic decision of making the transfer is often referred to as liberated from location, and therefore real-time communication has overcome the delay caused by distance. We are living in a wired world, where distance has lost its meaning and the knowledge incorporated into the decision making reflects the climax of informational techno-society. The Human life has become 'liberated' from the constraint of space and frictional effects of distance. Anything becomes possible anywhere and at any time. All information becomes accessible everywhere and anywhere."[68] (2) The Second 'traditional' area of geographical interest is the politics of networks. This relates to the ideas of surveillance, political regulation, civic influence and their future developments. There have been several discussions in the media about the possibility of individual surveillance. This is connected with the convergence of the mobile phone, computer and GPS (global positioning system). The geographical location and past time paths of a person's movements can be traced, even today, and the technology seems to be developing so quickly that personal privacy might be in jeopardy[69]. Another important aspect in the 'politics of networks' theme is related to the ideas of 'free speech', civic influence and democracy in the networks. Reference is usually made to the Internet, as it is the climax of the present network development. Generally, the potential of networks and electronic democracy are being acknowledged. The polarizing effect that IT might have on societal structure has been of particular interest in the field of social policy and welfare sociology. (3) Thirdly, IT and its developments have become part of 'societal evolution' as a whole. Therefore, all of the main genres of human geography are incorporated into the analysis. The contemporary network realm of globalization is concerned with the 'mixed and minced' type of research[70]. Analyses of networks and their social, cultural, economic and political impacts have led to the notion of space of flows and space of places. Briefly, the first of these notions refers to the transition in which the structures of society are being absorbed into various network-systems, and because of this the space of flows expands and regenerates. Many researchers from the traditional fields have continued their original interest, and the evolution that IT brought to their analyses was the adoption of the new situation, fast connection, efficiency profits and so on. In this light, IT can be evaluated as a new method or means of understanding the world economy, world politics or societal evolution and their developments.

Finally, the third and last of the 'main genres' may be defined as the 'new areas of cultural geography and the virtual embodiment of the human actor'. This means the subjective and theoretical interpretation of actors, conducts and spaces that are not only generated, but also regenerated through the networks. Two loose discourses in this genre may be separated as 1) the 'actor - body - identity' analyses and 2) 'cyberspace - virtual space - collective mental space' oriented analyses. Briefly, the first type of analysis refers to the mental idea of 'self' and to its complex (and dynamic) composition. The focus is on why, how and in particular where human actions, observations and insights take place and how they are experienced both by the actor - the self, and by the acted - the other[71]. The latter analysis, on the other hand, operates with one particular area of geographical interest - the concept of space and its definition. The main questions are related to different theoretical constructions of cyberspace, virtual spatiality and to the creation of virtual communities[72]. These emerging new misty spheres are dynamic in their nature and a new concept of telepresence has been introduced. Telepresence can be seen as a visualization of cyberspace where entities are transported and transfigured into certain types of cyber-entities. It is of the greatest importance to recognize that the research subject, or an arena of research has been generated inside the network, and the interest lies in actions, parameters and experiences that are produced in the network and their consequences. Naturally, these consequences can occur either in the network or in the real-world.

### *Digital Earth as a recognizer of the role of multiple stakeholders*

Digital Earth involves multiple stakeholders and actors. While the roles of environmental and social scientists, technologists and decision-makers are widely acknowledged, those of citizens in the development, use and management of Digital Earth have yet to be articulated. With several billion social network accounts, the opportunities to harness this wealth of digital data for a variety of applications, from emergency management and response to risk assessment, quality of life and environmental monitoring, cannot be ignored.[73] Assessing the quality of this data is an important issue but the contribution they can make in narrowing the gap between science and the public is potentially very significant.[74] This area includes research and ethical issues on privacy and confidentiality, openness and transparency versus security considerations, as well as the measurement of the social, economic and environmental costs and benefits of the deployment of Digital Earth. Whilst citizens' information provides new and exciting opportunities for collaborative and participative science[75], the development of web-enabled sensors adds a complementary dimension. During the last decade, a tremendous development and uptake of low-cost miniaturized sensors and wireless sensor nodes, has made it possible to treat equally all sensor-like information. This has led to the concept of the 'Observation Web' with observations originating from humans, sensors or numerical (environmental) simulations. Moreover, integrating the quantitative measurements and observations from sensors with the richness of qualitative information provided by citizens, makes it possible not only to assess how the environment is changing but also how such change is perceived. These dimensions are crucial for the interface between policy, science and society. Then, the Digital Earth is used at all ages: by children as a learning and play environment, by teenagers socializing and trending, by adults in their daily and professional life, and by the senior generation networking in their retirement with friends and family. As most objects have become web-enabled, from domestic appliances to buses, it is now possible to program and undertake activities in more interactive ways at home, the office, and on holiday. Energy efficiency, resource optimization and waste reduction are key greening principles enabled by this massive deployment of sensors. The accelerated pace of technological development is a challenge for policymakers to ensure that the legislative framework (especially in the interest of the privacy), and the institutional/organizational response is adequate in protecting individuals and avoiding threats to society.

Implementation of the Digital Earth vision is seen as most effective through a global public private partnership involving four key sectors of society- Research, Government, Commerce and Communities/Citizens (Civil Society). The research needed to underpin the development of Digital Earth is proposed to be addressed in partnerships among the large research funding organizations like the National Science Foundation in USA, the Chinese Academy of Science and the European Commission. The key technological innovations are however likely to come from the private sector, particularly through large industrial companies like Microsoft and Google, the telecommunications industry and through the collective effort of the open-source community. The key challenge is in communicating the Digital Earth vision, and building the strategic partnerships among the many stakeholder organizations. The ISDE has the leading role in building the alliances needed and coordinating the effort, while a network of communications companies is needed to promote the Digital Earth key advances and achievements and sustain the momentum.

These challenges are inherently embedded with spatial-temporal complexities, that is, they are almost entirely geographic in nature. Many of the structural issues impacting sustainable development goals can be analysed, modelled, and mapped using Earth observation data, which can provide the integrative and quantitative framework necessary for global collaboration, consensus and evidence-based decision making. Effective transfer of all relevant technologies and Earth-related data represents an important challenge[76]. However, under the Digital Earth framework, there are immense opportunities for digital transformation and sharing of resources. Achieving sustainable development will entail significant advances in overcoming political and technical bottlenecks to smooth the digital divide. Internet-based infrastructure with advancing 5G communication shows promise for expanding Digital Earth technologies to all nations.

As shown from this brief review of the literature on DE, there are multiple perspectives on Digital Earth. It is unlikely therefore that a single (revised) vision of Digital Earth will capture all perspectives from all stakeholders. There is not going to be a one-size-fits-all Digital Earth, but there will be a series of connected views of Digital Earth based on the same sources of data and offering users different functionalities. Based on the current social and technological trends and the review of the literature, one can identify certain important applications of the Concept.

### *Digital Earth: Potential Applications*

Joel Kotkin[77], renowned economic and social-trend forecaster, discusses how the digital revolution is changing where and how we live and work. The spatial analysis through digital mapping can transform education and society through better decision-making using the geographic perspective. This may be best accomplished in the various areas of geographic interest that may be more effectively understood and studied with the help of new technology. Embedded in studying these issues are core geography themes such as considerations of scale in patterns and processes; interpreting maps and analyzing geospatial data; understanding and explaining the implications of associations, networks, and interconnections among phenomena in places; defining regions and the regionalization process; establishing a sense of place; and understanding the nature and limitations of geographic data. The spatial perspective is critical to understanding the geographic content and processes. Being competent and confident in the application of the spatial perspective to geographic understanding enhances and strengthens geographers' ability to handle the discipline. A number of powerful web mapping and related tools such as ArcGIS Online (arcgis.com) and story maps (storymaps.arcgis.com) are now available for the geography instructor. As embodied in the concept and initiative of digital earth this brand new digital virtual world provides geographers with a fascinating new subject of study. Originating from these developments, Digital Earth prowess spread to a range of applications.

The field of geography has expanded from the earlier years of the discipline. The important work of mapping the world and exploring new countries and continents has changed to the abstract and difficult interpretation of information technology, analyses of flows of financial attributes and goods, and evaluation of the ever accelerating and transforming social and cultural realm of postmodern society. The tellers of the geographical story have changed, but in the end the very essence of the subject is still the same - to explore the world we know in the past, present and future[78]. The work of geographers relies on three major concepts: space, place and environment. These very same components are the ones which deal with a new idea of electronic environments and spaces.[79] In the two decades since the debut of the Digital Earth (DE) vision, a concerted international effort has engaged in nurturing the development of a technology framework and harnessing applications to preserve the planet and sustain human societies. To understand better some of the functionalities that may be required and to help develop the vision of Digital Earth 2020, it is useful to define a few exemplary cases. The section below shows examples of possible applications, both at global and individual level, particularly covering the studies on Physical, Environmental, Settlement, Land use, Population and Economic Geography.

*Environmental Studies*:

Digital Earth is an effective response to the global environmental changes those are threatening humanity. The global features of Digital Earth offer potential mainly for environmental applications such as global climate change; environmental assessments, environmental degradation, natural disasters response, disaster management, natural resource conservation and sustainable economic and social development[80]. Since the middle of 20th century, large-scale, high-intensity human activities and the rapid growth of the population and social economy have compounded global change problems such as global warming, air pollution, water pollution, land degradation, greedy resource exploitation, and biodiversity decline. Global change is recognized as a significant threat to sustainable development worldwide. To address these multidisciplinary issues at a global scale, global change research faces the unpredicted challenge of obtaining abundant data from the interacting subsystems of the Earth for analytical modelling and generating management decisions. Thus, it is important that Digital Earth facilitates the collection of data from various elements of the Earth system through monitoring the progress of global change in large-scale, long-term sequences, and aids in data processing, analysis, and simulation. Through continuous and long-term monitoring of the Earth system, scientists can use advanced geospatial processing technologies to simulate and analyse Earth’s dynamic surface processes and reveal spatio-temporal change mechanisms. Stakeholders will need to formulate scientific strategies and take progressive actions to respond to global change for sustainable development at varying local and regional scales. In this sense, big Earth data provides strong support to the Digital Earth vision, and is believed to strengthen new approaches to global change research. As, it provides a wide range of long-term sequences and multiple spatio-temporal scales to cover all of Earth’s systems including the atmosphere, cryosphere (the frozen water part of the Earth system)., hydrosphere, lithosphere and biosphere.

The environment is one key area where the application of computer power and related innovations holds considerable unexplored promise.[81] Environmental policy making has long focused on the need to manage shared natural resources in a sustainable fashion. Factories pumping emissions out of their smokestacks, or fishermen hauling too many fish from the sea, are just two classic examples of lost social welfare and ecological degradation they bring. Elaborate governmental regimes have been designed to redress these challenges. But our efforts often fall short. One reason is a lack of information. Not knowing who holds the environmental rights, what are the sources of harm, or the “fate and transport” of emissions, makes policymaking difficult. Information gaps also plague efforts to understand effects on health, and how to value those effects. Pollution may also arise from “waste”, reflecting the use of unsophisticated technologies, ignorance, or mistakes. Polluters or resource users would often be willing to switch to less harmful production or consumption practices if they had information about better alternatives. People have now learned, for example, that they can replace their traditional incandescent bulbs with high-efficiency fluorescent lighting, reducing electricity use and cutting both pollution and costs. Digital Earth provides opportunity for the technological breakthroughs that can help us to manage the environment better. The computer, with its extraordinary capacity to gather, sort, analyze, store and retrieve data represents a particularly important tool that is yet to be fully harnessed. And, beyond the extraordinary advances in information processing, progress is being made in related technologies such as sensors and telecommunications as well as in computer modeling and statistical analysis. These breakthroughs make it easier to spot environmental problems, assess their scope and seriousness, and understand their implications and effects. Technology and data also help to make the invisible visible, the intangible tangible, and the complex manageable. Advanced data analysis increasingly allows us, for instance, to understand cumulative impacts and to disentangle the interconnections among different environmental risks. Due to advances like these we now know that radon exposure represents a much greater threat to smokers than to those who do not smoke. A heat wave does not make the case for global warming, but long-term temperature trends might. Facts, figures, and tracking data on key indicators can narrow the range of environmental disputes and reduce the polarization that often marks policy debates today, whether about climate change or pollution of a local stream. New technologies also make it easier to identify better response strategies. Both corporate and public decision-makers are today able to compare policy options quickly and cost-effectively, obtain detailed information on experiences from elsewhere, and determine which interventions have been most successful. In short, environmental decisions can now be made with more data-driven and analytically rigorous underpinnings.

Information systems can transform our policy options as well. Just as property rights give farmers the incentive to manage their land on a sustainable basis, digital technologies can be deployed as “virtual barbed wire” to improve the management of shared resources and avoid their over-exploitation. Take fish stocks, for instance. The oceans were once seen as a limitless, open access resource, which any fisherman was free to exploit. But the result was inevitable: depletion of fish stocks. Today’s tracking and monitoring devices, however, make it possible to avoid a "tragedy of the commons" by allocating fishery shares and managing yields responsibly. In fact, one can imagine the day when citizens will be compensated directly by polluters, rather than having the government mandate investments in emission control or collect (and keep) pollution fees. Remote sensing, laser technologies, ion beam analysis, nano-technologies and other small-scale sensors will soon make it possible for virtually every pollutant to be tracked, measured, and even price tagged. Regulation more generally can be shifted towards more use of economic incentives and implementation of the Polluter Pays Principle. It won't be long before a monthly pollution invoice arrives with the electricity and phone bills. Computers have helped to refine product design and manufacturing, and in combination with progress in metallurgy and polymers, have reduced the material requirements for all kinds of products, from cars to soft-drink containers. In fact, a mid-sized car today weighs about 300 kilos (660 pounds) less than it did 25 years ago. New "smart" appliances, like computerized thermostats that turn down the heat when people are out of the house or asleep, are already helping to reduce environmental pressures. Biotechnology also holds great promise. Crops that do not require pesticides or fertilizers would be a boon to efforts to address water pollution and soil degradation. And the mapping of the human genome may make it possible to understand human susceptibility to various pollutants on an individualized basis. A data-rich world is also a more transparent one where comparisons are easy to make. With data readily at hand, environmental groups, community organizations and the media can more easily persuade governments and businesses into doing better. And greater transparency helps to smoke out cases where special interests are distorting policy choices.

Despite the downsides, the potential for environmental gains in the Information Age remains great. The process of applying digital power to the challenges of pollution control and natural resource management has just begun. For instance, today several plants and animal species are listed as endangered, threatened, or rare. By collecting information on terrain, soil type, annual rainfall, vegetation, land use, and ownership, scientists can model the impact on biodiversity of different regional growth plans[82]. By analyzing satellite imagery, researchers at the University of New Hampshire, working with colleagues in Brazil, for example, are able to monitor changes in land cover and thus determine the rate and location of deforestation in the Amazon. This technique is now being extended to other forested areas in the world[83]. Technology may not bring an end to environmental problems, but the advances that lie ahead could improve the chances of good policies actually working.

*Settlement studies*:

The Digital Earth provides a framework to produce global spatial information on population and settlements on the planet, identified as the Global Human Settlement Layer (GHSL). The GHSL is a multi-scale volumetric information layer describing artificial spaces where people live, work and enjoy life. Physical components such as buildings, roads and open spaces are accurately described at each scale from single rooms or apartments, to rural villages, towns or mega cities and other urbanized regions. The widespread use of Lidar and Digital photography has enabled the creation of this global layer in 3D, so that we can explore all built environments moving from the inside of buildings to the whole metropolis, including underground infrastructures and utilities. The Global Human Settlement (GHS) framework produces global spatial information about the human presence on the planet over time. This in the form of built-up maps, population density maps and settlement maps. The concept is useful in the study of Rural and Urban settlements, city planning, historical and current development of cities, site versus situation, and challenges faced by cities in Urban Development. Historically unprecedented forces are at work knocking cities, suburbs and towns across the country. In his *The New Geography*, Kotkin[84] focuses on the digital revolution's surprising impact on cities. Their traditional role as the centers of creativity and the crossroads for trade and culture is becoming ever more essential in a globalized information-age economy. This information is generated with evidence-based analytics and knowledge using new spatial data mining technologies. The framework uses heterogeneous data including global archives of fine-scale satellite imagery, census data, and volunteered geographic information. The data are processed fully automatically and generate analytics and knowledge reporting objectively and systematically about the presence of population and built-up infrastructures. Digital histories of buildings and cities available in Digital Earth also allow navigation through time (4D), and new planning proposals are regularly debated based on realistic models portraying the evolution of the city in the future. Sensor webs (exploiting satellite, aerial, ground and mobile sensors), connected to advanced pattern recognition algorithms and distributed processing capacities, produce an objective, globally seamless and constantly updated GHSL. Digital Earth allows different actors at different levels individuals, families, organizations or authorities to elaborate models and strategies concerning safety of living, travelling or working. At another scale Digital Earth allows the planning of collective rescue or mitigation measures after natural disasters and improved understanding of the interactions between human artificial spaces and natural environments. Through information, fusion of GHSL with crowd sourcing and mobile technologies integrated in the Digital Earth, it is possible to model the location of people at any point of space and time and consequently take informed decisions about risks or opportunities to crossspecific areas during specific events: to take the best escape route during a flood, or find the best place for communication. In the past, we used to take strategic decisions based on static population databases such as the Census, which reflected the resident population count every 10 years, and was therefore always out of date. Now we know the location of people (e.g., commuters, migrants, business people, etc.) at different times of day and night, and their use of space and facilities. We have moved therefore towards a much more dynamic and accurate understanding of the relationships between built environment and society: anywhere, anytime, at any scale.

### *Land Use Studies*

The examples of applications of Digital Earth to the land use studies are related, for instance, to Land-Use Zoning, Land-Use practices, Land use change and food production. According to one such case study[85] on the implications of switching to renewable energy resources, Farmers connect to Digital Earth to optimize their activity, close chronic yield gaps through improved management and have better coping mechanisms in case of disasters. The combination of field level weather forecasts, and sensors constantly measuring moisture and soil composition and acidity has made it possible to reduce the amounts of pesticides used by 50%. This has reduced significantly eutrophication, without loss of yield for the farmers. Instant information on markets, prices and delivery methods allows for rational crop rotation, and improved conservation of the resource base. Moreover, Digital Earth components specifically developed for farmers have automated several management operations through GPS (Global Positioning System) and GNSS (Global Navigation Satellite System) based geo-location tools (precision farming), and improved management through investments, loans or barter trade, supported through micro-insurance schemes that can be subscribed to in a tailored-way. Farmers now use Digital Earth services to supply information on local crop status and yields in exchange for long-term risk-analysis on price fluctuations in different markets, consultancy from fellow farmers, advice from market analysts on new trends (e.g., marketing of bio-labelled food), and early warning on emerging dangers (droughts, fire, flooding, hail and storms, frost, locusts). Increased communications and sharing of information among farmers and other actors in the processing and marketing chain has strengthened local communities and provided opportunities for better long-term planning. Speculation based on fragmented information and markets has thus been reduced. Digital Earth has enhanced our options to cater for the basic needs (food) of the ever-increasing global population. It has successfully helped remove poverty traps by creating safety nets, providing location and situation-based services, guidance and knowledge-packages, so that farmers are able to sustain our future. Moreover, the farmers are already beginning to use satellite imagery and Global Positioning Systems for early detection of diseases and pests, and to target the application of pesticides, fertilizer and water to those parts of their fields that need it the most. This is known as precision farming, or "farming by the inch." [86] Precision farming is about managing field variations (soil, climate and water) as accurately as possible to grow food with higher productivity in a sustainable manner, while reducing production costs and environmental impact. Technological development has resulted in an enormous scope of possibilities to achieve the above mentioned more effectively.

### *Disaster Mitigation*

Addressing natural and human-caused disasters remains the highest priority of all nations. Therefore, application of the Digital Earth framework and technology for disaster response and mitigation is of paramount importance. Today, novel solutions are expected from DE, which could significantly help realize disaster risk reduction (DRR) and Disaster Mitigation projects. In the frame of disaster risk mapping, geographic knowledge is crucial for making proper decisions. Notably, disaster-related applications have been prominent since the inception of the Digital Earth community. A comprehensive review of Digital Earth science includes, for instance, the examples of research on flood, coastal, river, and other disasters.[87] The Digital Earth has a great potential of progressively providing better solutions for disaster mitigation with the help of strong tools for data sharing and important potential for users, such as 2D or multi-D visualizations. Milestones of developments in early warning, disaster risk management and disaster risk reduction have been achieved. Improved solutions have been based on new research directions formulated in Sustainable Development Goals tasks and by expanding the possibilities of new effective solutions via newly organized data ecosystems generated by the United Nations Global Geospatial Information Management, the Group on Earth Observations and the Group on Earth Observations System of Systems, Copernicus and, more recently, the Digital Belt and Road initiative. The most important for disaster risk reduction are the basic theses of the U.N. Conference in Sendai.

In the past, Disaster Risk Management (DRM) was solved together with problems of the environment, subsequently developed relatively separately, and a new DRR trend enhanced their close cooperation in contemporary sustainable development efforts. There are two lines of development in U.N. documents in approaches to crisis situations, both natural and anthropogenic. They are:

(1) Environmental, linked to finding the most appropriate environmental approaches to solve planet Earth's problems. They are mainly oriented around concepts of sustainable development (SD), and

(2) The second line of development includes the Yokohama and Hyogo World Conferences (1994 and 2005), the Global Platform for Disaster Risk Reduction in Geneva in 2010 and the key concept of the "U.N. International Strategy for Disaster Reduction" (ISDR—United Nations International Strategy for Disaster Reduction).

Three United Nations Conferences focused on DRR have been held. First, the World Disaster Reduction Conference in Yokohama in 1994, which defined the Yokohama Strategy and Plan of Action for a Safer World: guidelines for natural disaster prevention, preparedness and mitigation. The Second World Conference on Disaster Reduction was held in Kobe, Japan from 18 to 22 January, 2005. The Hyogo Framework for Action (2005–2015) (HFA): Building the Resilience of Nations and Communities to Disasters was an outcome of the 2005 conference. The HFA set five specific priorities for action: (1) making disaster risk reduction a priority; (2) improving risk information and early warning; (3) building a culture of safety and resilience; (4) reducing the risks in key sectors; and (5) strengthening preparedness for response (WCDRR 2016). The third conference was the Third U.N. World Conference on Disaster Risk Reduction in Sendai, Japan in 2015 (United Nations General Assembly 2015). The Sendai Framework materials highlighted the need to tackle disaster risk reduction and climate change adaption when setting the Sustainable Development Goals, particularly in light of the insufficient focus on risk reduction and resilience in the original Millennium Development Goals (WCDRR 2016).

In the Third U.N. World Conference (U.N. DRR) on March 14, 2015 in Sendai, Japan, the Sendai Framework for Disaster Risk Reduction 2015–2030 was adopted (United Nations General Assembly 2015). The U.N. DRR conference is a culmination of contemporary state-of-the-art approaches to solve the problems of risks and disasters on our planet. The conference materials mentioned the role of Information and Communication Technologies (ICT), geographical information system (GIS), remote sensing, mapping, sensors, and volunteered geographic information. The Sendai Framework defined four new priorities of action: (1) Understand disaster risk; (2) Strengthen disaster risk governance to manage disaster risk; (3) Invest in disaster risk reduction for resilience; and (4) Enhance disaster preparedness for effective response and "Build Back Better" in recovery, rehabilitation and reconstruction (United Nations General Assembly 2015). These priorities are equally important to find better solutions, and the Digital Earth concept proves useful in addressing all of them. In addition, local and national organizations promote real-time access to reliable data, make use of space and in situ information, including geographic information systems (GIS), and use information and communication technologies innovations to enhance measurement tools and the collection, analysis and dissemination of data.

- *Demographic Research*

The systematic study of population dynamics and the causes and consequence of compositional changes in population has always been a data-driven discipline. Administrators have used censuses to count (and tax) populations since ancient times. In modern societies, an interest in data characterized the development of the discipline of demography. The spread of digital technologies and the increased access to the internet has contributed to the production and accumulation of unprecedented quantities of data about human behavior. Demographers, who have a long-standing interest in such issues, are in an ideal position to make sense of this new information. There are several ways in which the Data Revolution has created novel sources of data for demographic research[88]. There are unique technical and ethical challenges posed by these data sources. They also provide opportunities for understanding historical and contemporary demographic dynamics around the world. Demography is at the gates of a new data paradigm defined by the increased availability of population data produced or made available by digital technologies and the internet[89].The spread of the internet, the World Wide Web, and the Internet of Things, have accelerated this process, producing unprecedented data on society and human behavior.

There are three innovative sources of data that have been made possible by the Data Revolution and they offer great potential for conducting groundbreaking demographic research. First is digitization that has helped improve access to existing data, such as censuses and population registers[90], and bibliometric databases[91]. Similarly, the advent of online peer-to-peer collaboration has created new resources, such as massive online genealogical databases[92], that can be used for studying intergenerational demographic processes. Secondly, demographers can now analyze digital traces left by internet users in platforms like Twitter and Facebook (FB) to study population dynamics. Finally, the Data Revolution has created new opportunities for collecting primary data using devices connected to the internet.

The digitization of censuses and population registers was pioneered by the Integrated Public Use Microdata Series (IPUMS), which now hosts the world's largest collection of demographic micro data.[93] In time, digitization enabled the creation of crucial data repositories for demographic research (e.g. the Human Mortality and the Human Fertility Databases or digital national population registers) Nordic registers, for example, have been used to study intergenerational processes in fertility, health, mortality, and migration. Bibliometric databases, such as Scopus, Web of Science and Dimensions, are other examples of digitized sources with potential for demographic research. These databases contain data on millions of scientific publications produced each year, including author affiliation and addresses. Affiliation data can be used for analyzing scientific collaboration and mobility of researchers across countries. Despite several limitations, bibliometric data sources offer substantial benefits compared to traditional data sources like Surveys[94].These resources make research on migration of research-active scientists more cross-disciplinary, scalable, longitudinal, contemporary, and comprehensive.

Demographic data can also be crowd-sourced. Platforms like Geni.com and WikiTree have allowed thousands of amateur genealogists to collaborate in building large-scale online genealogical databases such as the Familinx database, which includes 86 million individual records from around the globe, with data that go back as far as the 17th century[95]. This database was scraped from Geni.com, a collaborative social network that allows users to find and verify family relations. Online genealogies are a promising resource because they cover long historical periods and are not restricted by national boundaries - on the downside, they are not representative samples and under-represent Low- and Middle-Income countries (LMIC).

About half of the world's population are active internet users and many use social media platforms like FB and Twitter.[96] Demographic information on the users of these platforms can be used to perform demographic research in a timely manner. Social media data can also be used to study populations that would otherwise remain entirely out of reach. Researchers can access FB and Twitter data using the platforms 'like Application Programming Interfaces (API). The researchers can access information that users have agreed to share, including text and images from tweets, user names, and tweet locations. Having access to individual-level Twitter posts gives researchers the freedom to design and test different models and algorithms using primary data. Data have been collected data using APIs to study contemporary social and demographic processes. FB data have been used to study access to digital technologies, immigrant cultural assimilation, and to estimate migrant stocks[97].Twitter data have been used to study migration flows[98], and monitor population health and natural disasters[99]. Despite several limitations, there are clear benefits in using this new source of data. For instance, demographers and sociologists have been able to reach and study new populations, while statisticians and computer scientists have had the opportunity to test new models and algorithms. These examples show how the internet has created research opportunities that were unimaginable when social networking platforms were initially conceived, over 20 years ago.

The Data Revolution has also created new opportunities for collecting primary data via the internet. Several studies have recruited participants for online surveys using social networking sites (as FB and Twitter) and online labor markets (as Amazon Mechanic Turk and Craigslist)[100]. Such platforms tend to have wide reach and often allow the targeting of individuals based on specific demographic characteristics, interests, and behaviours. This makes them attractive for both drawing convenience samples and recruiting members of hard-to-reach populations, usually at a lower cost than would be possible with traditional probability samples[101]. In addition to new platforms for survey research, internet-enabled devices (e.g., mobile phones and activity trackers) can revolutionize current research practice. Additionally, data collection via cell-phone applications could provide much needed insight into what people from various socioeconomic contexts and political regimes do during day-to-day life and how those activities are then linked to various measures of wellbeing. [102].

Finally, however, it is important to note that while innovative sources of data provide exciting opportunities for new research, they are unlikely to make 'traditional' demographic sources obsolete in the near future (e.g., surveys, censuses). Rather, the Data Revolution has the potential to complement and augment these existing data sources. Traditional population data, for example, are crucial for identifying systematic bias in online sources and calibrating estimates made from these data. Social media data can be used to estimate important demographic measures in contexts where traditional survey data are not available. The Data Revolution has already changed the way we do demography, as evidenced by the digitization of historical censuses and populations registers, and the creation of large-scale and open-access repositories of demographic data. The pace of this changes is likely to increase in the future as more researchers engage in ground-breaking research using digital data sources.

## I. CONCLUSION

A geospatially literate population is the goal of geographers in the 21st century. Such a population is better equipped to recognize, understand, and resolve those critical issues, whether local or global, that will confront us today and in the future. New technologies have always been important in advancing geographic understanding, but never have they been so thoroughly and rapidly transformative of the discipline as at this stage in geography's evolution. The revolutionary potential of information technology breakthroughs is significant. Just as new technologies have profoundly expanded both research possibilities and the knowledge base of other disciplines, such as biology, physics or medicine, so too are the revolutionary new geographic technologies developed during the past few decades extending frontiers in geographic research, education and applications. This trend is still accelerating, as the integration of geographic technologies, such as the global positioning system and geographic information systems, is creating an explosion of new "real-time, real-world" applications and research capabilities. The resultant dynamic space/time interactive research and management environments created by interactive GPS/GIS, among other technologies, places geography squarely at the forefront of advanced multidisciplinary research and modeling programs, and has created core organization management tools (geographic management systems) which will dramatically change the way governments and businesses work in the decades ahead.

By now, most people and things are online at all times. This situation is creating a paradigmatic shift in the way we relate to each other and with our surroundings. Hence, it is argued that Digital Earth is a dynamic framework to share information globally and improve the collective understanding of the complex relationships between society and the environment we live in. Digital Earth makes it possible to navigate across space and time, connecting the global issues to local ones. It includes scientific models to project into the future and help us all understand how the Earth system works and what are the likely consequences of our actions or inactions. It has, therefore, become the framework for negotiating international accords on the environment but also on acceptable ethical conducts, as the potential dangers from the development of DE are possibly as big as the opportunities.

Implementing this vision of Digital Earth requires a major effort in international collaboration as well as further advances in science and technology. The key challenge is therefore in developing the framework of governance across multiple stakeholders and the public to harness these new developments, and direct change so that Digital Earth emerges as an open framework accessible to all to shape the future of our planet. Geographers have the vision, now it's their turn to convert it into reality.

Like the Web, the Digital Earth would organically evolve further over time, as technology improves and the information available expands. Rather than being maintained by a single organization, it would be composed of both publicly available information and commercial products and services from thousands of different organizations. Just as interoperability was the key for the Web, the ability to discover and display data contained in different formats would be essential. In the long run, we should seek to put the full range of data about our planet and our history at our fingertips.

Digital Earth is an evolving concept that is strongly influenced by the evolution of technology and the availability of new data. In a couple of years, the Earth will be revisited several times a day by the new generation of satellites, and real-time observation will no longer be an unreality. As we look to the future, it is unlikely that a unified vision of Digital Earth will capture all the perspectives of all stakeholders. A one-size-fits-all Digital Earth would not be appropriate for all nations and cultures. The current social and technological trends expressed in the literature prescribe a robust and comprehensive list of likely characteristics for an updated version for Digital Earth, which closely follows the original vision. There will be a series of connected perspectives of Digital Earth based on varying priorities and applications of the same framework data sources operating with different user-specified functionalities. In the future, the concept and vision of Digital Earth will evolve with the development of science and technology.

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## NOTES

1. Rana, L. (2020),
2. Lange, L. (1999),
3. Daniel Sui & Richard Morril, (2004),
4. Martin Hilbert (2011),
5. Miller, Vincent (2011),
6. Longley et al. 1998; Geocomputation involves combination of four leading edge technologies: GIS, which creates the data; Artificial intelligence (AI) and computational intelligence (CI), which provide smart tools; High performance computing, which provides the power; and Science, which provides the philosophy.
7. Soja, E. (1989); MacMillan, B. (ed.) (1989); Brunn, S.D. and Leinbach, T.R. (1991) & Castells, M. (ed.) (1985).
8. Starrs, P.F. (1997),199,
9. Adams, P. (1997), 155,
10. Hall (1993); Chen (2002),
11. Openshaw (1994); Cliff (1970)
12. Brunn, S.D. (1998),
13. MacDougal (1976),
14. Miller and Han (2001),
15. Kotkin, J. (2001),
16. Craglia, M. et al (2008),

17. Albert Arnold Gore Jr. (born March 31, 1948) is an American politician and environmentalist who served as the 45th vice president of the United States from 1993 to 2001. After his term as vice-president ended in 2001, Gore remained prominent as an author and environmental activist, whose work in climate change activism earned him (jointly with the IPCC) the Nobel Peace Prize in 2007. Gore is the founder and current chair of The Climate Reality Project, the co-founder and chair of Generation Investment Management, a member of the Board of Directors of Apple Inc., and a senior adviser to Google.
18. Gore A.A. (1992, 1998).
19. Richard Buckminster Fuller (1895 –1983) was an American architect, systems theorist, author, designer, inventor, and futurist. In 1962, he proposed a giant, 200-foot diameter miniature earth to be called the Geoscope, the most accurate global representation of our planet ever to be realized. It was a proposal to create a 200-foot-diameter (61 m) globe, which would be covered in colored lights so that it could function as a large spherical display. It was envisioned that the Geoscope would be connected to computers which would allow it to display both historical and current data, and enable people to visualize large scale patterns around the globe. Many of Fuller's ideas for the functions of the Geoscope are now being realized by virtual globes.
20. International Society for Digital Earth (2012)
21. Goodchild, M.F. (2000),
22. Ballatore, Andrea (2014),
23. Grossner et al. (2008),
24. Goodchild, M.F.et. al. (2012),
25. Guo et al. (2014),
26. "The Digital Earth - Al Gore". digitalearth-isde.org. 1998-01-31. Retrieved 2015-10-13.
27. Zhen Liu, et. al. (2019),
28. Craglia et al. (2012),
29. Grossner and Clarke (2007)
30. www.digitalearth.gov
31. Craglia et al. (2012), *op.cit.*
32. Craglia, M. et al (2008),
33. Zhen Liu, et. al. (2019), *op.cit.*
34. A geobrowser, or a virtual globe, is a three-dimensional, computer generated representation of the Earth or another world.
35. A spatial data infrastructure (SDI) is a data infrastructure implementing a framework of geographic data, metadata, users and tools that are interactively connected in order to use spatial data in an efficient and flexible way. Another definition is "the technology, policies, standards, human resources, and related activities necessary to acquire, process, distribute, use, maintain, and preserve spatial data"
36. Geosensor is defined as "any device receiving and measuring environmental stimuli that can be geographically referenced.
37. Zhen Liu, et. al. (2019), *op.cit.*
38. Chen,S. (1999); Goodchild (1999, 20080; Foresman (2008); Guo et al. (2009); Annoni et al. (2011); Craglia et al. (2012); Goodchild et al. (2012).
39. Chen, S. (1999).
40. Zhen Liu, et. al. (2019), *op.cit.*
41. Zhen Liu, et. al. (2019) Foresman, (2008),
42. International Society for Digital Earth, (1999),
43. Sheate et al. (2007); UNEP (2007),
44. Goodchild et al. (2012). *op.cit.*
45. Goodchild (1999), *op.cit.*
46. Zhen Liu, et. al. (2019), *op.cit.*
47. Craglia et al. (2008) and Annoni et al. (2011), *op.cit.*
48. Adams, P. (1997), 155.
49. Grossner (2007),
50. Gore, A. (1999),
51. Goodchild (2000), *op.cit.*
52. Guanhua, X. (1999)
53. Wu and Tong (2008)
54. Guo et al. (2010)
55. Goodchild, Michael F. (2000).
56. Simply stated, Noosphere is the part of the biosphere that is affected by human thought, culture, and knowledge. It represents the stage of evolutionary development dominated by human mind and reasoned thought. It is the sphere of human consciousness and mental activity especially in regard to its influence on the biosphere.

57. The term 'Noosphere' comes from French *noösphère*, based on Greek *noos* (mind, reason). The concept, however, is accredited to a two authors, the French philosopher Pierre Teilhard de Chardin and the biogeochemist Vladimir Vernadsky. The founding authors developed two related but starkly different concepts, the former being grounded in the geological sciences and the latter, in theology. In the theory of Vernadsky, for instance, the Noosphere is the third in a succession of phases of development of the Earth, after the geosphere (inanimate matter) and the biosphere (biological life). Just as the emergence of life fundamentally transformed the geosphere, the emergence of human cognition fundamentally transforms the biosphere. Vernadsky's Noosphere emerges at the point where humankind, through the mastery of nuclear processes, begins to create resources through the transmutation of elements. Teilhard, on the other hand, perceived a directionality in evolution along an axis of increasing *Complexity/Consciousness*. For Teilhard, the noosphere is the sphere of thought encircling the earth that has emerged through evolution as a consequence of this growth in complexity / consciousness.
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61. Norgaard, Richard B., (1994),
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63. Zhen Liu, et. al. 2019, *op. cit.*
64. Worboys (1995)

65. Gatrell, A.C. & M. Löytönen (eds.) (1998)
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