

**ESCAP Technical Paper**  
Information and Communications Technology and  
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# **Good Practices for Promoting Regional Cooperation in Space Applications for Sustainable Urban Development, Water Resources Management and Transportation Management**

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Prepared by Space Applications Section  
ICT and Disaster Risk Reduction Division  
ESCAP

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## Abbreviations

ARMAS	Active Road Management Assisted by Satellite
ESCAP	United Nations Economic and Social Commission for Asia and the Pacific
DENR	The Philippine Department of Environmental and Natural Resources
DPWH	The Philippine Department of Public Works and Highways
FAO	The United Nations Food and Agricultural Organisation
GEOSS	Global Earth Observation System of Systems
GIS	Geographic Information System
GNSS	Global Navigation Satellite Systems
IGS	International GNSS Service
ISRO	Indian Space Research Organization
JAXA	Japan Aerospace Exploration Agency
MDGs	Millennium Development Goals
NOAA	National Oceanic and Atmospheric Administration
OCHA	The United Nations Office for the Coordination of Humanitarian Affairs
RESAP	Regional Space Applications Programme for Sustainable Development
RIMES	Regional Integrated Multi-Hazard Early Warning System for Africa and Asia
RS	Remote Sensing
TEWS	Tsunami Early Warning system
TRMM	Tropical Rainfall Measuring Mission
TSR	Tropical Storm Risk
UAV	Unmanned Aerial Vehicle
UN-GGIM	United Nations initiative on Global Geospatial Information Management
UN-SPIDER	United Nations Platform for Space-based Information for Disaster Management and Emergency Response
UNCSD	United Nations Conference on Sustainable Development
UNDAC	United Nations Disaster and Assessment and Coordination
UNEP	United Nations Environment Programme
UNESCO	The United Nations Educational, Scientific and Cultural Organization
UNOOSA	United Nations Office for Outer Space Affairs
USGS	The United States Geological Survey
WMO	World Meteorological Organisation

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## 1. INTRODUCTION

Science, technology and innovation (STI) is a key driver of sustainable economic growth. Expanding research and development (R&D) in STI is the most efficient way to better understand key global challenges, make a more forward-looking analysis, and devise solutions rooted in a scientific foundation. For example STI can aid in reducing carbon emissions, improving energy efficiency, encouraging climate change resilience, and addressing disaster impacts. Among innovative technologies, space technology and geospatial information system (GIS) applications have emerged as one of the leading technologies that contribute to sustainable economic growth and global development challenges in the Asia Pacific region.

Over the last three decades, space technology applications have gained ground in terms of spread of its usage and the advancement of capabilities associated with said usage. The increasing recognition of the gap between capability and use since the 1990s prompted organizations to launch programs to bridge the gap between providers and users (Wagner, Verhoest, Ludwig, & Tedesco, 2009). The availability of low-cost and readily useable datasets and increasing education and practical research has raised the technological awareness of professionals at both national and local levels every year (Sivanpillai, 2008). The high costs of hiring experts in industrialized countries and the poor physical accessibility of many global regions are boosting the use of Earth observation techniques. Another important driver is preparation for natural disasters and mitigation of the damage” (VTT Technical Research Center, 2014).

The use of space technology has been accelerated by developments in information and communications technology (ICT). Reduced infrastructure cost, improved hardware and broader internet connections increase the accessibility of satellite derived information. With more people getting involved with the study of Space Technology, applications can now go beyond traditional topographic and terrain mapping (Landenberger & Deagen, 2011).

Space technology applications and space-derived information have acted both as an enabler and as a catalyst for global, regional and country efforts in progressing toward internationally agreed Millennium Development Goals (MDGs) and Sustainable Development Goals (SDGs) that will form part of United Nations’ development agenda beyond 2015. Furthermore, space technology applications and space-derived information serve as effective and innovative tools to support the implementation of MDGs and forthcoming SDGs. They have contributed to the productivity and efficiency of sustainable economic growth and poverty reduction by providing essential information and guidance; sustainable urban development by creating an urban inventory, thematic maps, and queries for identifying most vulnerable urban areas; improved decision making by providing scientific evidence for climate change impact and mitigation measures in inaccessible areas; and contributed to meeting the basic needs of MDGs by providing data to support resource management, transportation, agriculture and disaster risk management. Furthermore, space technology applications and geospatial information such as tele-medicine are indispensable in the fight against infant and maternal mortality,

malaria, HIV/AIDS and other diseases identified in the MDGs. Tele-education targeting women can bring quality educational opportunities to the uneducated women and children in even the most remote of villages and also enhances employment opportunities for female professionals (SDG 4).

This paper sets out to show how space technology and geospatial data, combined with non-space derived data such as socio-economic data, can enhance the understanding and observation of global issues. More specifically, this paper discusses how space technology and geospatial data can play an important role in providing valuable information such as trends in climate change, patterns of urbanization, mapping of water resources and GPS in trans-boundary regional transportation. This paper will also show that despite the wide range of benefits associated with the use of space applications, many developing countries in the Asia-Pacific region do not have sufficient access to this important technology, thus depriving them of innovative space-based solutions to both current and future issues.. It is here where regional cooperation can play a vital role in facilitating greater accessibility to space technologies and GIS applications.

The paper at hand is prepared with two objectives in mind: (1) to compile and analyze good practices and lessons learnt in space technology and GIS applications in the areas of sustainable urban development, water resource management, transportation management, as well as regional cooperation on space technology applications; and (2) based on the analysis and findings, to provide policy and technical recommendations on how to optimally use space technology and GIS applications for sustainable development.

## **2. KEY CONTRIBUTIONS OF SPACE TECHNOLOGY APPLICATIONS TO MDGS AND SDGS**

### **2.1 Contributions to MDGs**

The member States of the United Nations announced the Millennium Development Goals (MDGs) at the United Nations Headquarters in New York, in September 2000 as part of its goal to “achieve international co-operation in solving international problems of an economic, social, cultural, or humanitarian character”. The MDGs constitute a set of time-bound and measurable goals, targets and indicators for combating poverty, hunger, disease, illiteracy, environmental degradation and discrimination against women. They include inter alia: halving the proportion of people whose income is less than one dollar a day; halving the proportion of people who suffer from hunger; achieving universal primary education and gender equality; reducing under-five mortality by two-thirds; reducing maternal mortality by three-quarters; reversing the spread of HIV/AIDS; and halving the proportion of people without access to safe water. Most of these targets are to be achieved by 2015. In the process of achieving these goals, space technologies and GIS have contributed substantially towards the provision of crucial knowledge and data to inform better decisions regarding how to sustain and improve life on Earth in the overall context of the MDGs (Czar Samiento, 2014).

During the past 10 years, it has been fully recognized that space-referenced information systems, when used appropriately to take into account the differing needs of people, are central to facilitating the achievement of all MDGs. Earth observation data and the convergence of the nature and application of satellite data with airborne data could also be used in the generation of digital elevation models, (DEMs) for mapping. The advances in GIS, associated GIS software, and Global Navigation Satellite Systems (GNSS) have helped to make geospatial information a major source of data for government, commerce and industry. The collective progress in this type of technology is important in eradicating poverty, creating jobs and promoting the achievement of several MDGs.

The Global Earth Observation System of Systems (GEOSS) 10 Year Implementation Plan (Altan, 2009) demonstrated the possible applications in the sectors of development as seen in the table 1 below.

Table 1: Areas of Societal Benefit from Earth Observation.

Area	Task Short Title
<i>Agriculture</i>	Data Utilization in Agriculture Forest Mapping and Change Monitoring Training Modules for Agriculture Improving Measurements of Biomass Agricultural Risk Management Operational Agricultural Monitoring System
<i>Biodiversity</i>	Biodiversity Requirements in Earth Observation Capturing Historical Biodiversity Data Biodiversity Observation and Monitoring Network Invasive Species Monitoring System
<i>Climate</i>	Sustained Reprocessing and Reanalysis Efforts Key Climate Data from Satellite Systems Key Terrestrial Observations for Climate GEOSS IPY Contribution Global Ocean Observation System Seamless Weather and Climate Prediction System
<i>Disasters</i>	Seismographic Networks Improvement and Coordination Integration of InSAR Technology Implementation of a Tsunami Early Warning System (TEWS) at Global Level Multi-hazard Zonation and Maps Multi-hazard Approach Definition and Progressive Implementation Use of Satellites for Risk Management Implementation of a Fire Warning System at Global Level Risk Management for Floods
<i>Ecosystems</i>	Ecosystems Integrated Global Carbon Observation (IGCO) Ecosystem Classification

	Regional Networks for Ecosystems Global Ecosystem Observation and Monitoring Network
<i>Energy</i>	Using New Observation Systems for Energy Management of Energy Sources Energy Environmental Impact Monitoring Energy Policy Planning
<i>Health</i>	Forecast Health Hazards Strengthen Observation and Information Systems for Health Environment and Health Monitoring and Modeling Integrated Atmospheric Pollution Monitoring, Modeling and Forecasting
<i>User</i>	Identify Priorities and Synergies between SBAs Pilot Communities of Practice Nowcasting and Forecasting User Applications Millennium Development Goals Environmental Risk Management
<i>Water</i>	Forecast Models for Drought and Water Resource Management In-situ Water Cycle Monitoring Capacity Building Program for Water Resource Management Global Water Quality Monitoring Satellite Water Quantity Measurements and Integration with In-situ Data
<i>Weather</i>	Surface-based Global Observing System for Weather Space-based Global Observing System for Weather THORPEX Interactive Global Grand Ensemble (TIGGE) Numerical Weather-Prediction Capacity Building Data Assimilation for Operational Use Weather Demonstration Project for the Beijing 2008 Olympic Games

Source: The Global Earth Observation System of Systems (GEOSS) 10 Year Implementation Plan (Altan, 2009).

Table 1 above is a comprehensive summary of the potential benefits of GEOSS. It is apparent that GEOSS is therefore a powerful tool in combating poverty (MDG 1), through their contribution to sustained economic growth, enhanced market efficiency, and creation of employment opportunities. For example, the application of space technology in agriculture has the potential to increase food production through better soil management, eco-efficient water resource management and efficient irrigation resulting in high-yield crops with enhanced food value. Projects on space science and technology such as the Famine Early Warning System (FEWS) in Africa help in monitoring and predicting the potential onset of drought-induced famine and provide countermeasures through the use of planned agriculture. Utilization of remote sensing and GNSS techniques improve the precision of agriculture practices and generate jobs for the populace.

Space technology and geospatial information systems have also contributed to combating HIV/AIDS, malaria, and other diseases. Tele-medicine and GIS can aid in

much the same way they aid child mortality and maternal health (MDG 4 and 5). Microgravity can greatly help in growing HIV protease inhibitor crystals that, arguably, would help find a potential cure or vaccine. Space technology is also key in tackling the challenges associated with population growth, urbanization, climate change, water crisis, deforestation, biodiversity and energy sources (MDG 7). For example, meteorological and Earth observation satellites provide essential data for hazard mapping, risk assessment, early warning and disaster relief. Similarly, unexpected hazards such as oil spills and wildfires can be monitored and managed using space technology. For instance, a very basic but essential requirement for tackling the problems stemming from unexpected hazards is gathering information on where the problem is located, what is there and how to get there. Existing maps are frequently out-of-date, especially in less developed areas, but satellite images can provide up-to-date information in the case of an emergency.

## **2.2 Expected Contributions to SDGs**

In June 2012, Heads of State and high-level representatives met at Rio de Janeiro, Brazil, for the UNCSO Rio+20. The UNCSO Rio+20 aimed to renew country commitments to both sustainable development and to the promotion of an economically, socially and environmentally sustainable future for our planet, both for present and future generations. To this end, the UNCSO Rio +20 vowed to eradicate poverty, promote sustained economic growth, respect all human rights, protect the environment, enhance gender equality and provide equal opportunities for all. The mutual agreements and resolutions in the conference produced the document “The Future We Want”, which includes the creation of the post-2015 development agenda. Since the UNCSO Rio+20, the United Nations Open Working Group on Sustainable Development Goals has produced 17 proposed sustainable development goals (SDGs) in July 2014 for further consultations among member States and key stakeholders – all of which are set to be achieved by 2030 (United Nations Open Working Group on Sustainable Development Goals, 2014).

The outcome document “The Future We Want” emphasizes the importance of scientific knowledge and technology for sustainable development. In particular, it recognizes that scientific knowledge and evidence-based approaches play an integral part in achieving SDGs. In this regard, applying space science and technology to sustainable development involves three key approaches: (a) addressing basic needs through innovation and capacity building in areas such as poverty reduction, agriculture, urban planning, resource management and disaster risk reduction; (b) promoting innovation and innovative approaches which will lead to sustainable economic growth and job creation; and (c) promoting global and regional cooperation for better management of global challenges; working together to find global pictures and compile global information. In particular, when space-derived information is integrated with ground socio-economic information, it results in a more synergic approach to achieving SDGs. Given the potential benefits of connecting these types of data, a system / platform to integrate space – derived information and socio-economic ground information should be developed at national and regional levels.



Space technology and GIS applications are expected to contribute to socio-economic growth that aids in meeting the basic needs of people, such as food, water, sanitation, health, housing and transportation through providing basic and fundamental information and data. Recent complex combinations of socio-economic situations require more advanced knowledge and capacity along with more accurate and comprehensive data in order to address complex challenges, in particular in remote and isolated areas such as climate change in the Antarctic and trans-boundary transportation (SDG 1). With respect to addressing the issue of global food security, space-based and aerial image technology can help in precision agriculture, rainfall and drought observation and monitoring crop wellness with the end goal of maximizing land productivity without damaging the ecosystem - all in an effort to address the issue of global food security. High-resolution airborne and satellite images are currently being used to assess crop growth and yield variability in order to predict supply (Yang, Everitt, Du, Luo, & Chanussot, 2013).

Space technologies and GIS can aid countries in their efforts to establish improved water resource management such as in dam construction, sustainable river water redirection and rainfall pattern observation. Improved water resource management ensures the availability and sustainable management of water and sanitation for all (SDG 6). One example of space technology aiding in water resource management is in the AQUIFER project. The AQUIFER project focuses on the development and demonstration of Earth observation based products and services which support national authorities and international institutions in the transboundary management of two prominent internationally shared groundwater resources - aquifers - in Africa, the North-Western Sahara Aquifer System and the Iullemeden Aquifer System (Saradeth, Dodo, & Latrech, 2010).

As seen in previous cases of the transformative application of space technology into ordinary life, Science Space Technology (SST) played a crucial role as driver of innovation and sustainable economic growth. With regard to sustained, inclusive and sustainable economic growth (SDG 8), SST is a growing field with potential job creation and other economic opportunities. The growth of industries utilizing space-based technologies, either from government initiatives or private sector partnerships, will call for training and employment of space scientists and professionals, regardless of gender and social status.

For building resilient infrastructure, promoting inclusive and sustainable industrialization and fostering innovation (SDG 9), GIS and space-based technologies can greatly assist economic and social planners in selecting cost-effective and geographically sound locations, which aids in ensuring uninterrupted service in the wake of disasters such as earthquakes, floods and other natural calamities. For example, the European Space Agency partnered with Portuguese companies to initiate the Active Road Management Assisted by Satellite (ARMAS) project, aimed at monitoring road network traffic and hazards for efficient transport (European Space Agency, 2006)

To ensure access to affordable, reliable, sustainable, and modern energy for all (SDG 7), remote sensing and GIS are currently being utilized for determining prime locations for forms of renewable energy, particularly in the solar, wind and hydroelectric platforms. Satellite remote sensing and meteorological modeling are extensively used in preliminary, low-cost and national-scale mapping of wind, solar and bio-energy resources that can be tapped in Mali (Nygaard, et al., 2010). Geologists make use of satellite-based synthetic aperture radar (SAR) and gravitation sensors to detect natural seepages of oil and thus pinpoint potential oil reserves (Benoit, 2012) – the latter of the two technologies having great potential for utilization in the Arctic (Technical University of Denmark, 2009).

Space-based technologies can also aid in urban planning and national heritage protection, especially when there is a need to address the strain of urbanization on ecosystems and the potential existence of geo-hazards in development areas and cultural and natural heritage sites (SDG 11). The potential use of satellite images in urban planning has been explored since the 1980's when Landsat images were made available, and satellite images of cities were used in countries such as Pakistan and Turkey. Three-dimensional GIS has been used for exploratory spatial analysis in predicting human activities and movements (Kwan & Lee, 2004).

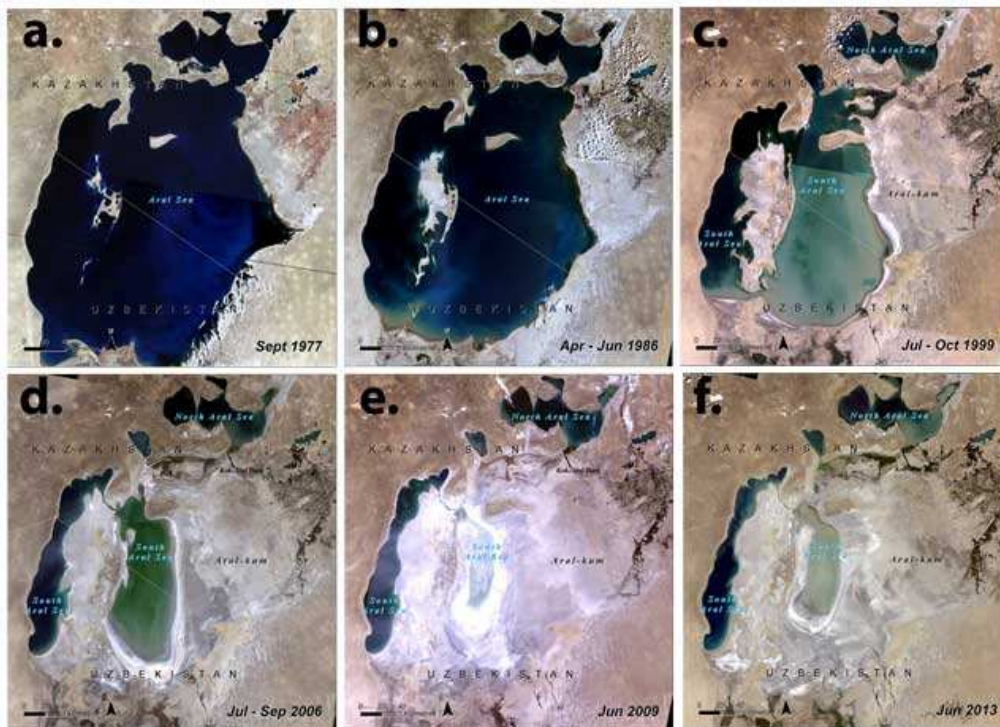
Remote sensing and GIS can aid in planning for increased and sustainable production of renewable resources such as agricultural, forestry and marine resources, and also aid in developing tools for sustainable tourism that create jobs and promote local culture and products (SDG 12). The recent trend in forestry practice is to develop complete Management Information Systems (MIS) which provide the framework for all levels of planning. GIS is the basic tool for such an approach (FAO Regional Office for Asia and the Pacific, 1999).

Determining the responsibility and accountability of a nation to its territorial seas and its corresponding marine resources has been a highly contentious issue. Therefore strict implementation of the agreements made in the United Nations Convention on the Law of the Sea (UNCLOS) is significant in fostering sustainable management of marine resources. Investing in improved remote sensing technologies and GIS for oceanography will greatly assist in marine ecosystems management, as well as encourage nations to take an intelligent approach in managing resources found in their territorial seas conducive to conservation and sustainable use of the oceans, seas and marine resources for sustainable development (SDG 14).

Moreover, geospatial technologies have contributed to protecting, restoring and promoting sustainable use of terrestrial ecosystems, sustainably managing forests, combating desertification, reversing land degradation, and halting biodiversity loss (SDG 15). For example, as seen in the Figure 1, space technologies have been used to monitor terrestrial ecosystems by looking at land cover change and keeping track of desertification and wildlife habitat determination. To raise social awareness in achieving state accountability, digital cartography techniques can produce custom-made maps and visualizations that will be both interesting and intelligible to concerned communities.

Geomapping and digital cartography can be utilized in many areas of sustainable development by promoting peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels. Moreover it can serve as a valuable tool in disaster management, before, during and after the onset of natural disasters (SDG 16).

[Figure 1] Two images of Aral Sea.



Source: Images provided by USGS EROS Data Center. Image compilation prepared for Nature.

### 3. GOOD PRACTICES IN SPACE TECHNOLOGY AND GIS APPLICATIONS

The General Assembly of the United Nations, in its resolution 68/75, emphasizes the need to increase the benefits of space technology and its applications, and to contribute to sustained economic growth and sustainable development, including building resilience to reduce the consequences of disasters, in particular in developing countries. Other United Nations reports also discuss the role of space applications; including the 2014 Report of the Secretary General of the United Nations on Coordination of Space-related Activities within the United Nations system: directions and anticipated results for the period 2014-2015 - addressing the post-2015 development agenda, and the 2014 Report of the United Nations Committee on the Peaceful Uses of Outer Space.

Similarly, the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP), through the adoption of ESCAP Resolution 68/5 and 69/11 Implementation of the Asia Pacific Plan of Action for Applications of Space Technology

and GIS for Disaster Risk Reduction and Sustainable Development 2012-2017 in 2013, also acknowledged the potential benefits and contributions of space technology and its applications to sustainable development. ESCAP has supported member States in implementing the Asia-Pacific plan of Action for Application of Space Technology and GIS for Disaster Risk Reduction and Sustainable Development 2012-2017 (Asia Pacific Plan of Action) under ESCAP resolutions 68/5 and 69/11 in the years 2013 and 2014 respectively. In doing so, a significant step was made towards enhancing the awareness and knowledge of policy makers. A forum for sharing good practices, knowledge and technology through regional cooperation has been established with the Space Applications Programme for Sustainable Development for Asia and the Pacific. A part of these resolutions discusses using space technology and GIS applications to implement disaster risk reduction and sustainable development in accordance with the “The Future We Want” outcome document and the Hyogo framework.

### **3.1 Space Technology Applications for Sustainable Urban Development**

Considering that almost half of the population of Asia and the Pacific live in cities and more than half of the world's mega-cities (13 out of 22) are now found in the same region (ESCAP: 2013), there is an increasing need for urban planning that utilizes digital technologies to mitigate the adverse effects that stem from rapid urbanization. To offset pressure on city infrastructure, a proper planning process that incorporates effective and innovative solutions, products and services is essential.

Proper city planning using space-based technologies will ensure that vital economic and social infrastructure, government facilities, and assets located in cities are as protected as possible. Above all, proper planning will take into account the fact that the most affected populations in many emergency situations are the marginalized poor people living in cities – i.e. slum dwellers in developing countries – who tend to live along river banks, on hillsides and slopes prone to landslides, near polluted grounds, on decertified land, in unstable structures vulnerable to earthquakes, and along waterfronts in coastal areas (UN Habitat: 2014). Moreover, it is essential to analyze good practices related to space technology and GIS for sustainable development as well as to identify persistent challenges faced by cities.

Space technology and GIS applications are important tools in sustainable urban planning. The GIS displays graphical digital elevation models (DEM's) and Digital Terrain Models (DTM's) using elevation and topographic data in urban planning and monitoring. The required land cover or soil type factor in infiltration and precipitation rate over the land are held in GIS, in the form of satellite image data or map data. The factors influencing storm water runoff flow and how this affects cities are integrated into powerful software that drives complex computations which yield accurate predictions of potential future scenarios. This proves extremely valuable in helping cities identify and assess important issues such land use allocation, land cover by run-off population, housing patterns, drainage systems, urban development patterns, effective environmental monitoring and infrastructure resilience against future natural disasters.

### *3.1.1 GIS for urban planning: land use allocation, land cover by run-off population, housing patterns, and drainage systems*

GIS is particularly useful in predicting land use allocation and land cover by run-off calculation. When a satellite image or digital area photograph is superimposed over an image that was captured earlier, GIS can reveal spots where changes have occurred, however the capacity of detecting very small changes is fully dependent on the resolution of the satellite images in use. Tang et al. (2005)<sup>1</sup>, presented the Runoff MINimization (ROMIN) model that can be used for sorting between sites for land use allocations. This model compares the soil type of the site in combination with the proposed land use and calculates the resultant runoff. By comparing different land use options and their associated runoff, it is possible to identify where the minimal runoff land use will occur.

Land use allocation that incorporates consideration of existing natural ecosystems found within cities is another good case of where space technology and GIS applications could be utilized. Monitoring urban development is as important as urban planning. Planning urban areas is not sufficient in itself, these plans must be detailed, comprehensive and strategic and furthermore, such plans must be carefully followed. GIS and state-of-the-art Earth observation as well as geospatial data capturing technology is without doubt the most robust and effective environmental monitoring system available today. The capacity to detect changes in the environment long before on-site inspectors can even see them is particularly useful in urban development monitoring. For instance, with GIS as a tool, mapping an entire city in broad ecosystem groupings is possible. Over-urbanization induces flash floods and gully erosion and with the use of GIS, these occurrences can be drastically mitigated if not completely avoided. GIS-based hydrologic studies and predictions also lend well to the mitigation of flash floods and gully erosions in urban areas. It is also important to integrate vegetative cover in cities in order to hold soil particles together and shade them from baking under the sun, while acting as filtering agent of the air pollutants. GIS facilitates the planning of planting grass lawns and trees on paved walkways to increase this vegetation cover.

A GIS-based urban drainage network design is a powerful tool that can be used in sustainable urban development. GIS data shows the natural drainage route design which ensures efficiency at several levels including the best positions for installing the drainage systems needed to serve the entire sub catchments in a responsible manner. This method also provides indispensable information in a number of other areas such as the velocity of runoff in each sub catchment which is useful in water-borne disease studies; the run-off coefficient maps of the studied area and so on.

Due to the constant threat from its unique position in the Pacific ‘Ring of Fire,’ Japan has invested heavily in modern Earth observation methods for public works and

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<sup>1</sup> Tang Z, Engel BA, Lim KJ, Pijanowski BC, Harbor J (2005). Minimizing The Impact of Urbanization on Long Term Runoff (Paper No. 040103). J. Am. Water Resour. Association. [https://engineering.purdue.edu/ABE/People/.../minimizing .pdf](https://engineering.purdue.edu/ABE/People/.../minimizing.pdf) - United States.

safety. This mature planning system provides infrastructure resilience. Potential of natural disasters must be assessed and determined by extensive hydrological and geological research. Japan has been developing its Integrated Earthquake Disaster Simulation Systems, an integration of computer science, earthquake engineering and Spatial-Temporal GIS database technology. Not only is this needed for rapid emergency operations but it also paves the way to better city planning and production of city maps (Goto, Takeuchi, & Shigeru, 2004).

### 3.1.2 GIS for urban planning: urban development patterns, effective environmental monitoring and infrastructure resilience

China's rapid economic and population growth requires urban expansion. A comprehensive and continuous study of its urbanization processes and urbanization patterns has been under way for quite some time. In this connection, the government of China has been increasing the space technology and GIS applications to address urban planning, urban water and disaster management and urban environment challenges including city traffic (Hui Lin 2014).



Source: Prof. Dr. Hui Lin's presentation 2014.

The building geometries and landscape features of Singapore's high-rise housing and high-rise buildings were studied in correlation with medium-resolution thermal data images from Landsat. The study showed that different thermal patterns at different times of the year occur due to the building geometries as derived from image data revealing differences in solar azimuth. Also, the different temperatures at different orientations and elevations show that thermal data are good indicators of urban heat (Nichol, 1996).

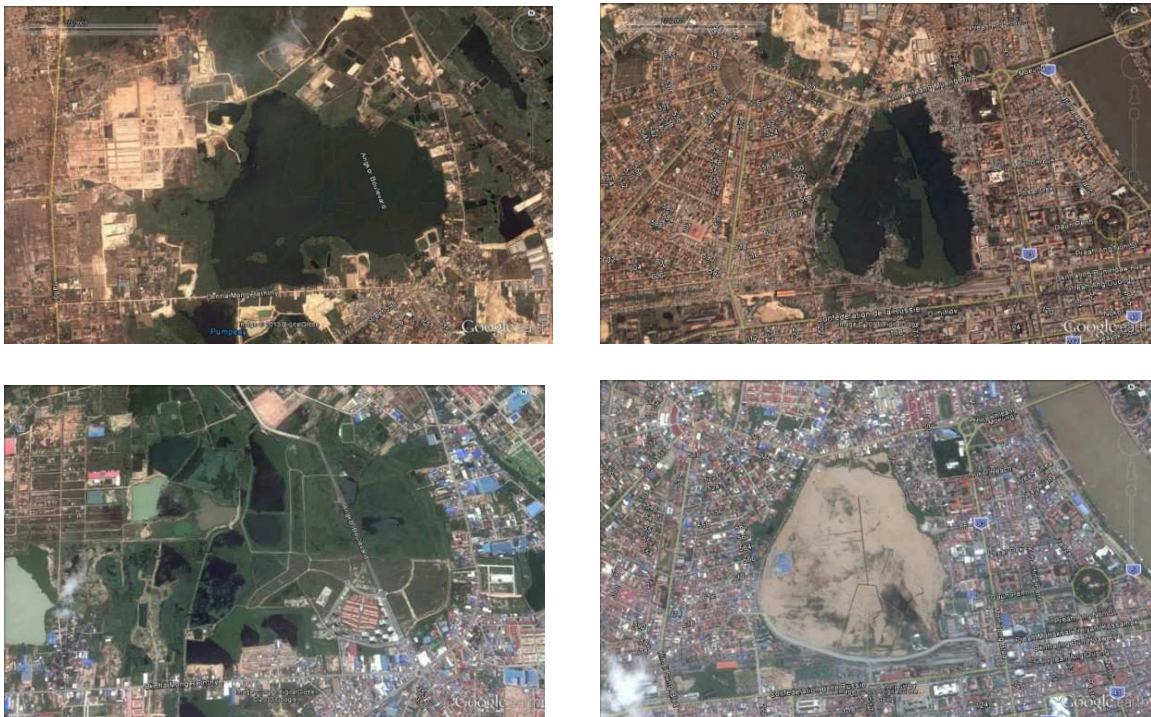
Urban heat study (Pereira & Lopez in 2004) by using space and GIS applications, characterizes the spatial pattern of the urban heat island (UHI) phenomenon when in situ measurements are not available. The formation of urban surface heat islands became apparent from the comparison of medium resolution thermal imagery. The impact of urbanization to surface urban temperature is noticeable– the average annual rate of urban growth is found to be 1.33 percent while the rise of UHI has an annual growth rate of 0.8



degrees Celsius. Likewise, an increase in land surface temperature has been related to a decrease in leaf biomass. These were evident from changes in land cover parameters such as fractional vegetation cover and surface moisture availability. These parameters were derived by computing the normalized difference vegetation index (NDVI) from the images. Urban growth has brought with it a corresponding increase in land surface temperature (Czar Samiento 2014).

Recent ESCAP studies in pilot cities such as Ulaanbaatar, Dhaka and Phnom Penh also highlight the potential use of space technologies to identify and assess the urban development patterns (sprawls), including change of green land, population and housing patterns. In the pilot cities, urban expansion also destroyed the original natural surface and farm land. Air and water quality degradation and destruction of wetlands caused extreme damage to the ecological environment of cities, resulting in environmental degradation; the disappearance of local characteristics of the rural landscape and cultural landscape, and the reduction of urban green space, thereby affecting the quality of the urban environment. For example, analyzing the data in 2014 it was found that the two wetlands have disappeared in Dhaka and that urban patterns spread to low-lying areas below the flood discharge level, causing floods. The same situation also occurred around Boeung Pong Peay Lake in Phnom Penh, Cambodia between 2003 and 2013 as shown in Figure 2 below (Shujing Yang 2014, ESCAP).

[Figure 2] Boeung Pong Peay Lake and Boeung Kak Lake in 2003 and 2013, Phnom Penh.



Source: Image - Google Earth, from Shujing Yang.

### **3.2 Space Technology Applications for Water Resources Management**

A large number of space technology applications and space-borne platforms address water-related issues.. Space-derived information can be used extensively in water management and combined with non-space technologies, can play an important role in addressing many water-related issues, including understanding and observation of global water cycles and unusual climate patterns, mapping of water courses, monitoring and mitigation of the effects of floods, droughts and earthquakes and improving the timeliness and accuracy of weather forecasts. This leads to an improvement in early warning systems operated at regional, national and local-community levels and helps to mitigate flood- and water-related risks to vulnerable populations. Having this information and knowing how to use it also aids in developing effective responses to natural disasters.

Technically, the Tropical Rainfall Measuring Mission's (TRMM) Microwave Imager used to measure the brightness temperature of radiation is a good example of promoting space technology for water resource management. It uses optical remote sensing to record radiation from the visible and infrared range. Land and water surfaces are delineated through their differences in wavelengths (Parida & Oinam, 2008).

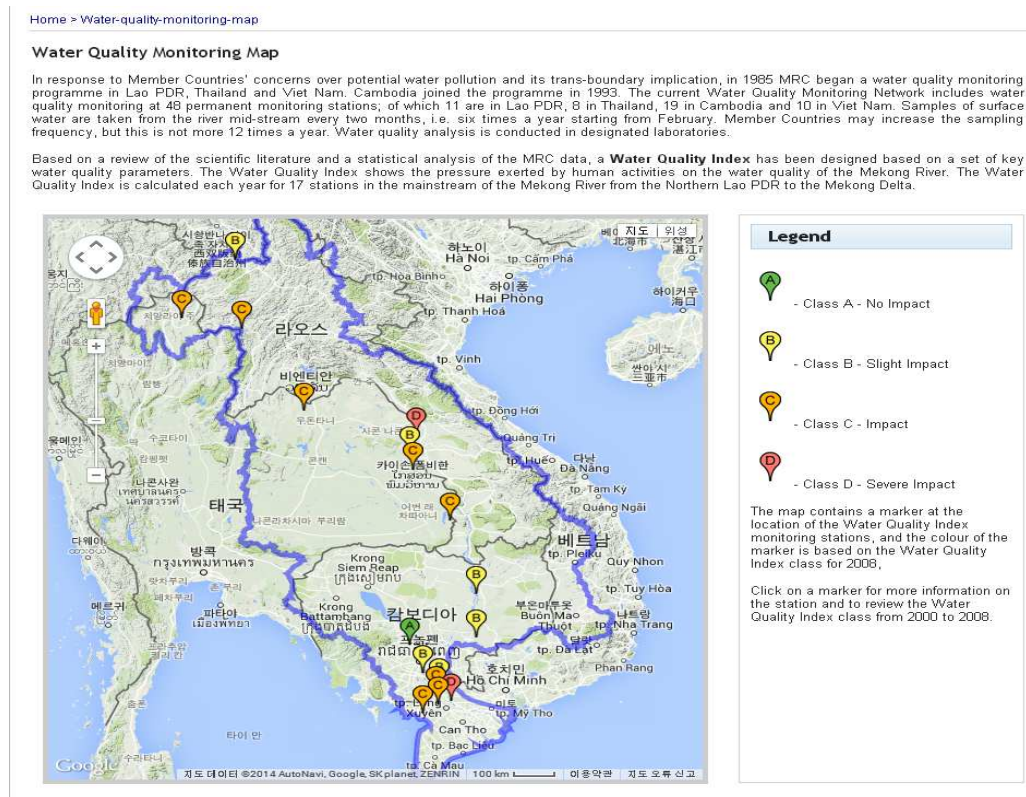
In terms of renewable energy production, space technology and GIS are often used to gather parameters aiding production estimates. Some common applications currently are for geothermal and hydroelectric power. For geothermal energy, strategic exploration and management technologies such as remote sensing are used in order to reduce risks and improve sustainable geothermal energy production fields (Meneses III, 2013). An added benefit is that hydroelectric power structures assist in controlling floods. The dam structures are built to create a water reservoir, a hydraulic head and a water surface (Vischer & Hager, 1998). Reservoirs are vital components of water management systems as they offer several benefits including a more reliable water supply and the possibility of hydropower generation. Multipurpose dams create operational problems that come from, ironically, its different purposes. The multi-objective nature of the reservoir, in addition to the multi-stakeholder environment defined by local laws and policies, requires alternative and dependable inflow estimation and forecasting methodologies to support the complex decision-making in water resource management (Warner, 2007).

In China, space-derived data assisted in the creation of a hydrological model of China's Huaihe River and other river systems. Envisat data were then laid on the application to determine other elements related to the water cycle and water resources management. Annual rainfall and precipitation data were used to predict and monitor seasons that historically correlated with the highest water demand. Based on these, the Three Gorge Hydropower Plant effectively released water for relief during dry seasons (Jiren & Mancini, 2012).



The Mekong River is an international river passing through a number of countries. Therefore, the management of the river requires collaboration among countries in the river basin. The Mekong River Commission (MRC) was established for the collaboration among the basin countries including Cambodia, Lao People's Democratic Republic, Thailand, and Viet Nam. As a part of their cooperation, the MRC designed a website called MRC Data and Information Services. This website allows basin countries to share information on water level and water quality of the Mekong River based on in situ measurements done by each member periodically. For example, water level information is updated every fifteen minutes for 48 stations around the member States, and water quality information is updated every two months for 17 stations.

[Figure 3] Example of MRC Data and Information Services.

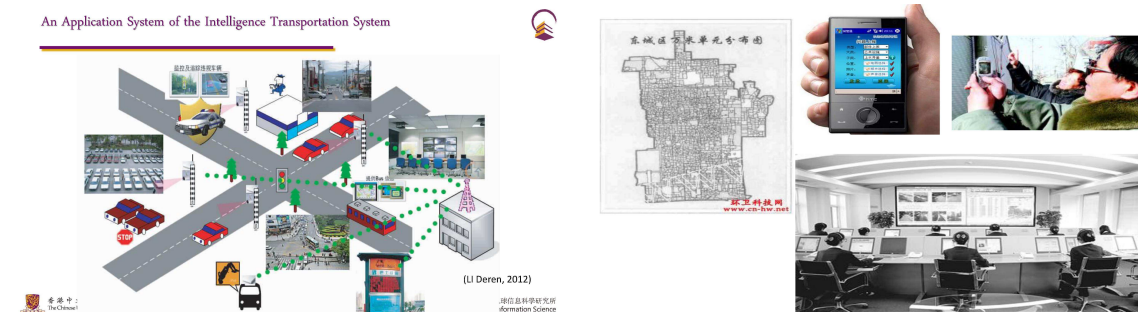


### 3.3 Space Technology Applications for Transportation Management

In maritime and inland waterway sectors, space technology and GIS applications are used to track control, container and ship-to-ship coordination, port approach and navigation, ship-to-shore coordination, shore-to-ship management and calamity abatement. With more than 50,000 ships around the world and 15,000 boats on EU inland waterways, Galileo (Europe's own global navigation satellite system), combined with GPS, can contribute to a safer and more efficient navigation owing to the better accuracy and availability provided. The GNSS applications in road transport cover much more than in-car navigation: for instance, GNSS-based toll collection systems allow for a more

efficient use of the road infrastructure, reducing both traffic flow and adverse environmental effects. Fleet management and logistics can also benefit from the accuracy brought by European Geostationary Navigation Overlay Service (EGNOS) and Galileo, by locating in real-time, trucks, buses, taxis, etc. This helps optimize resources, facilitates better fleet management and reduces time and fuel consumption.

As seen in the picture below, GIS, remote sensing and GNSS are also being used extensively for land transportation and traffic management. The National Consortium for Remote Sensing in Transportation - Environment (NCRST-E) studied the benefits of remote sensing for transportation planning (Goodman, Laymon, & Meyer, 2005). The research indicated that to locate or relocate existing transportation facilities in a cost-effective manner, information about corridor terrain is required. This information is used to design and evaluate alternative alignments and grades for alternative corridor locations. The traditional method of collecting this information has been ground surveys and photogrammetric mapping which are both time consuming and expensive.



Source: Professor Dr Hui Lin's presentation 2014.

#### 4. EXISTING REGIONAL COOPERATIVE FRAMEWORKS

There is a growing concern about the expanding digital gap between developed and developing countries regarding access to space technology and space-derived data and information. Even with current efforts to develop the technology and scientific methodologies to exploit space observations, the existing gap between the capabilities of developed and developing countries effectively slows down both collaboration and coordination. The lack of scientific data in developing countries and the inability to analyze the available data represents a significant challenge. Making valuable data available to developing countries and forging stronger collaborations are two methods to aid developing countries in building local capacities. The cost of capacity building (processing and analyzing data), however, is often very high for developing countries (Barbiere, 2013). This clearly presents an opportunity for regional cooperation - especially between developed countries and developing countries.

Below is an overview of existing international and inter-regional cooperation agreements expected to continue to contribute to enhancing regional policy frameworks

for the application of space technology applications in the name of cultivating a culture of working together in a more integrated manner.

(1) RESAP

During the Ministerial Conference on Space Applications for Development in Asia and the Pacific, held from 19 to 24 September 1994 in Beijing, and endorsed by the Beijing Declaration on Space Technology Applications for Environmentally Sound and Sustainable Development in Asia and the Pacific, a Regional Space Applications Programme for Sustainable Development in Asia and the Pacific (RESAP) was officially launched. RESAP enhances regional coordination and cooperation through the promotion of effective applications of space technology for sustainable development in Asia-Pacific. The programme aims to directly assist developing members and associate members of ESCAP by integrating space technology applications into development planning for achieving sustainable development in the region.

Since the founding of RESAP in 1994, ESCAP has made concerted efforts to promote the application of space technology and Geographic Information Systems (GIS) for supporting both disaster risk reduction and inclusive and sustainable development in the region. For example, to avoid the loss of life and minimize economic losses in times of disaster and emergency ESCAP responds promptly to requests for support by disaster affected member States. Upon receiving requests for support from affected countries, often at the onset of a disaster, the network of space agencies within RESAP immediately mobilizes in providing satellite derived products and services. . Satellite derived products and services include scenes of near real-time and archived satellite imagery as well as damage maps, provided by RESAP members and ESCAP's strategic partner UNITAR/UNOSAT.

In recent years, the activities under the RESAP framework have been focusing on: (a) the provision of near real-time satellite imagery to countries affected by severe disasters; (b) the operationalization of the regional cooperative mechanism for drought monitoring and early warning (the Regional Drought Mechanism); (c) capacity building to address the main gaps and emerging challenges to using space technologies and GIS for disaster risk reduction and sustainable development in developing countries; and (d) research and policy analysis on the application of emerging technologies and available resources.

ESCAP gives high priority to capacity-building programmes. For example, during 2013-2014, ESCAP conducted a series of training workshops featuring specialized training on space technology and GIS applications with the long-term vision of effective disaster risk reduction, which benefitted approximately 300 government officials, policymakers, administrative officials, planners, professional staff, researchers and project managers from approximately 30 developing countries in the region. Some of these capacity-building activities are conducted through the Centre for Space Science and Technology Education in Asia and the Pacific (CSSTEAP) with a RESAP training node in Dehradun, India. There are also training partners in the People's Republic of China,

Indonesia, Thailand and other countries. The training is conducted in collaboration with ESCAP's strategic partner UNITAR/UNOSAT.

In addition, through the RESAP network and in collaboration with ESCAP's strategic partner UNITAR/UNOSAT, ESCAP has facilitated access to space-based data for member States upon receiving requests from disaster-affected countries. From 2012-2014 ESCAP mobilized more than 200 satellite images and damage maps upon receiving requests for support by affected countries for disaster early warning, preparedness, response, relief and damage assessment.

Under RESAP, the ESCAP Secretariat also promoted strategic partnerships and cooperation with the UN-SPIDER, UNDP, UNISDR, UN-GGIM, UNOCHA, FAO, WMO, APRSAF, APSCO, Sentinel Asia, the International Charter on Space and Major Disasters (the Charter); the ASEAN Coordinating Centre for Humanitarian Assistance on Disaster Management (AHA Centre ); the Disaster Management Center of South Asian Association for Regional Cooperation (SAARC DMS), CSSTEAP, RIMES, SOPAC, the Global Water Partnership (GWP) and the Asian Institute of Technology (AIT).

As expressed in ESCAP resolutions 68/5 and 69/11, the application of space technologies and GIS have contributed significantly towards addressing issues relating to sustainable development. Specifically through targeting disaster risk reduction and disaster management, as well as the environment and development in the region. This was further reiterated through acknowledgement and key commitments in the Rio+20 outcome document on information and communications technologies in the areas of space and GIS applications. This additional recognition covers the importance of comprehensive hazard and risk assessments, knowledge and information sharing, including reliable geo-referenced information and the importance of early warning systems. This contributes to effective disaster risk reduction at all levels and aims to reduce economic and social damage including the loss of human life.

## (2) UN SPIDER (Global and Regional)

The recent past has seen the development of several initiatives that have made space technologies available to help humanitarian efforts and emergency response during disasters. The United Nations Platform for Space-based Information for Disaster Management and Emergency Response (UN-SPIDER) was established to focus on ensuring the accessibility and usage of space technologies in all phases of the disaster management cycle which also includes the proactive risk reduction phase that lessens life and property losses.

UN SPIDER uses space technology to address the need of various agencies in different countries by providing them access, resources and capacity-building regarding how to apply Earth-directed space technology, data and information to manage disasters, and major natural or man-made hazards. It features an emergency mechanism that will provide data to the most important global mechanisms the International Charter for Space and Major Disasters.

The SPIDER platform also provides its users with guides and case studies, methodical workflows and best practices as well as scientific and technical articles on space technology and disasters to aid in the decision-making process during disasters.

### (3) Asia-Pacific Regional Space Agency Forum

The Asia-Pacific Regional Space Agency Forum (APRSAF), established in 1993, aims to enhance space activities in the Asia-Pacific region. Space agencies, governmental bodies, and international organizations, such as the United Nations, as well as companies, universities and research institutes from over 30 regional participants take part in APRSAF. With the ever increasing attendance of high-ranking officials, APRSAF presents an opportunity to discuss international cooperation for space activities in concrete terms.

APRSAF currently organizes four working groups: Earth Observation (EO), Communication Satellite Applications (CSA), Space Education and Awareness (SEA), and Space Environment Utilization (SEU), to share information about the activities and future plans of each country and region in each of the respective areas. APRSAF also supports the establishment of international projects aimed at common issues such as disaster and environmental protection so that participating parties can collaborate with each other.

One key activity is the Climate Regional Readiness Review for Key Climate Missions (Climate R3), which was formed in Australia with the theme of “The Role of Space Technology and Industry in Addressing Climate Change”. It was endorsed as an APRSAF initiative at APRSAF-18 in Singapore, 2011. Climate R3 was formed to encourage Asia-Pacific cooperation wherever possible and encourage Asia-Pacific data flow beyond borders. It exists to relay the significance of satellite missions for climate information needs to different bodies. The goal of this initiative is to evaluate regional benefits of different climate-related satellite missions; to further increase the awareness of these benefits to the Asia-Pacific region; to encourage the use of information gathered by space satellites; to consider possible measures in increasing the regional capacity and leverage global investment; and to relay the significance of climate missions. Climate R3 was created to ensure that Asia-Pacific issues are properly represented in the context of global space-related initiatives and that the region effectively applies and participates in said initiatives.

### (4) Regional Integrated Multi-Hazard Early Warning System for Africa and Asia (RIMES)

RIMES is an institution that was formed after the Indian Ocean tsunami in 2004. It is owned and managed by its member States namely: Bangladesh, Cambodia, Comoros, India, Lao PDR, Maldives, Mongolia, Papua New Guinea, Philippines, Seychelles, Sri Lanka and Timor-Leste. It was developed to promote the generation and application of an

early warning system inside a multi-hazard framework. It was established in April 30 2009 and registered with the United Nations on July, 1 2009.

This institution exists to provide regional early warning services and raise the capacity of its member States in the end-to-end early warning of tsunami and hydro-meteorological hazards. Furthermore, they exist to build capacity and provide warning information that can be executed towards being forearmed, forewarned and resilient.

RIMES provides its constituents with key services like a Tsunami Watch Provision to the National Tsunami Warning Centers under the UNESCO/IOC framework. This focuses on the seismic, sea level and Deep Ocean monitoring, exchange, process, analysis and archiving of data and providing alerts and bulletins on earthquake and regional tsunamis. In addition, RIMES provides Hydro-Meteorological Research and Development Support to National Meteorological and Hydrological Services under the WMO framework. This includes (a) the development of decision-support tools and new generation risk information products, (b) an analysis of risks to climate variability and change and (c) identifying risk management and adaptation options. It also helps in the capacity building of national and local level agencies in the development of an end-to-end early warning system.

#### (5) CSSTEAP

In 1990, the Center for Space Science and Technology Education in developing countries was established in response to United Nations General Assembly Resolution (45/72, 1990). When a United Nations team ran an assessment of six countries in the Asia-Pacific region in 1994, a recommendation by UNOOSA for the establishment of the Centre for Space Science and Technology Education in Asia and the Pacific (CSSTEAP) was proposed. CSSTEAP started in 1995 with 10 members with the Government of India's Department of Space as a host. The Department of Space in Dehradun, India provided the facility and field expertise.

Through research and education, CSSTEAP is an institution that is able to actively interact in the development and transmission of knowledge in space science and technology fields. It focuses on providing in-depth educational and application programmes through Post Graduate level courses in the Remote Sensing and Geographic Information System (RS and GIS), Satellite Communications (SATCOM), Satellite Meteorology and Global Climate (SATMET), Space and Atmospheric Science.

In the Remote Sensing and Geographic Information System programme, the graduates are expected to be able to enhance the skills and knowledge of professionals in different countries. Graduates are expected to be able to aid in policy development as well as the planning, development and management processes of RS and GIS applications, ultimately to enhance the self-reliance of their country so that the need for external experts will eventually decrease.

#### (6) APSCO

In 2005, an intergovernmental organization of fourteen states called the Asia-Pacific Space Cooperation Organization (APSCO) was formed with the goal of developing space technology in the region. The member States must agree to cooperate in Space technology and programmes of its applications; Earth observation, disaster management, environmental protection, satellite communications and satellite navigation and positioning; space science research; education, training and exchange of scientists / technologists; establishment of a central data bank for development of programs of the organization and dissemination of technical and other information relating to the programs and activities of the organization, and; other cooperative programmes agreed upon by the member States (Asia-Pacific Space Cooperation Organization).

The specific objectives are: (1) To promote and strengthen the development of collaborative space programs among its Member States by establishing the basis for cooperation in peaceful applications of space science and technology; (2) To take effective actions to assist the member States in areas such as space technological research and development, applications and training by elaborating and implementing space development policies; (3) To promote cooperation, joint development, and to share achievements among the Member States in space technology and its applications as well as in space science research by tapping the cooperative potential of the region; (4) To enhance cooperation among relevant enterprises and institutions of the member States and to promote the industrialization of space technology and its applications; (5) To contribute to the peaceful uses of outer space in the international cooperative activities in space technology and its applications.

## **5. INVESTMENT TRENDS IN SPACE TECHNOLOGY**

The utilization of space-derived technology has been growing in recent years as more and more governments are showing interest in investing in space-referenced information systems and geospatial technology. However, it seems that interest is predominantly shown from developed or emerging countries.

Ronal Van der Linden, director-general of the Royal Observatory of Belgium noted that “substantial investment in space research can provide significant economic returns, as is the case in developed countries” (Ng'andwe, 2013).

One indicator that is useful to track the development of space technology and geospatial data infrastructure is the percentage of government expenditure on research and development (R&D) for space and Earth observations. The graphs and analysis below for government expenditure on R&D in space and Earth observation demonstrate trends and investment patterns of OECD member countries<sup>2</sup>. The first graphs show the comparative size of investment in space technologies of OCED countries<sup>3</sup>. The charts

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<sup>2</sup> Data source: OECD stats.

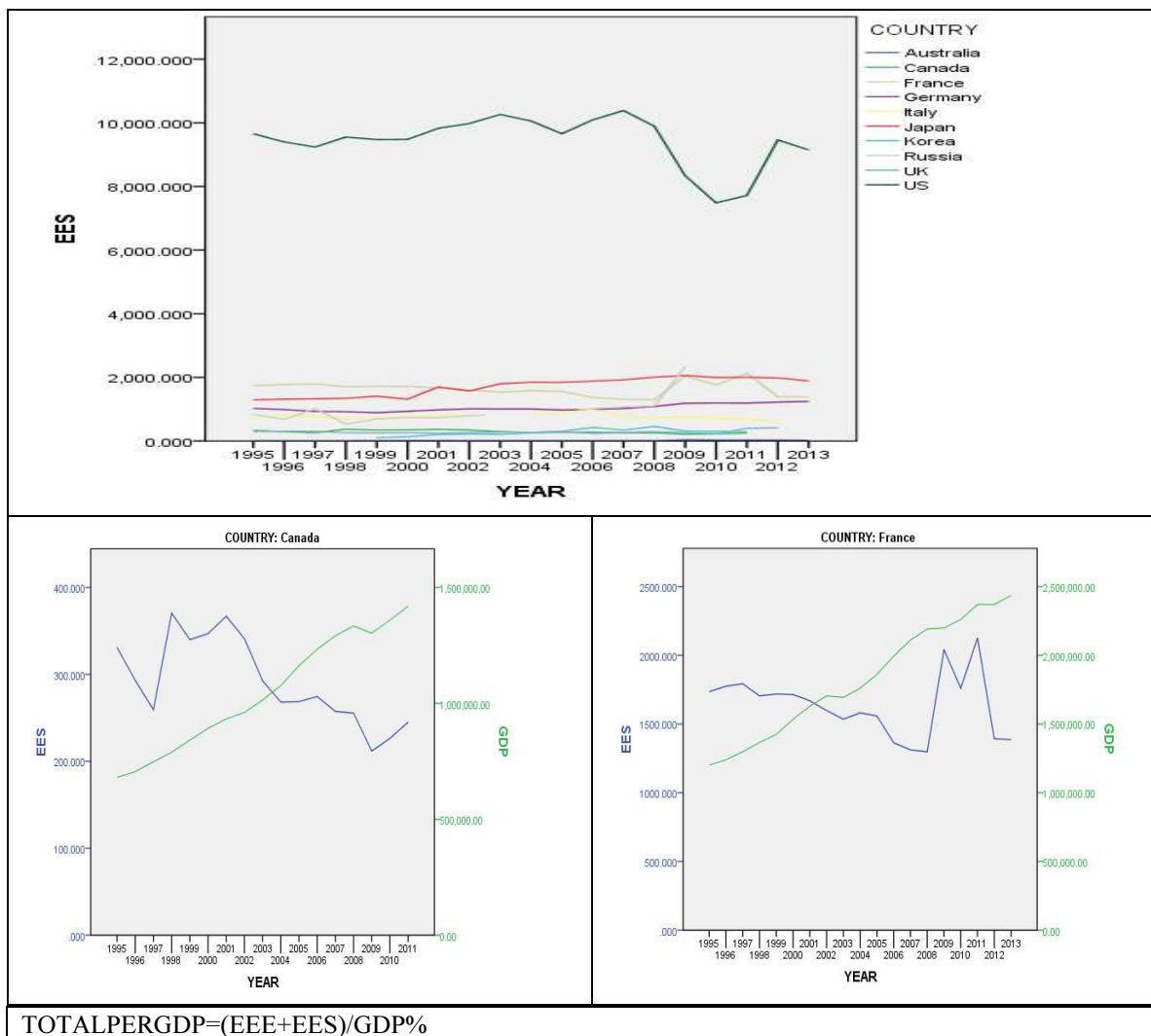
<sup>3</sup> EEE: Government expenditure in exploration and exploitation of the Earth (million 2005 dollars) and EES: Government expenditure in exploration and exploitation of Space (million 2005 dollars).

above show the annual trend of government R&D expenditure in exploration and exploitation of space (EES; million 2005 dollars). These graphs indicate that the USA has invested relatively more compared to other OECD countries active in the exploration of space and Earth. However the general trends of the USA show the economic crisis for 2008-2009 decreased expenditure in space and Earth observation.

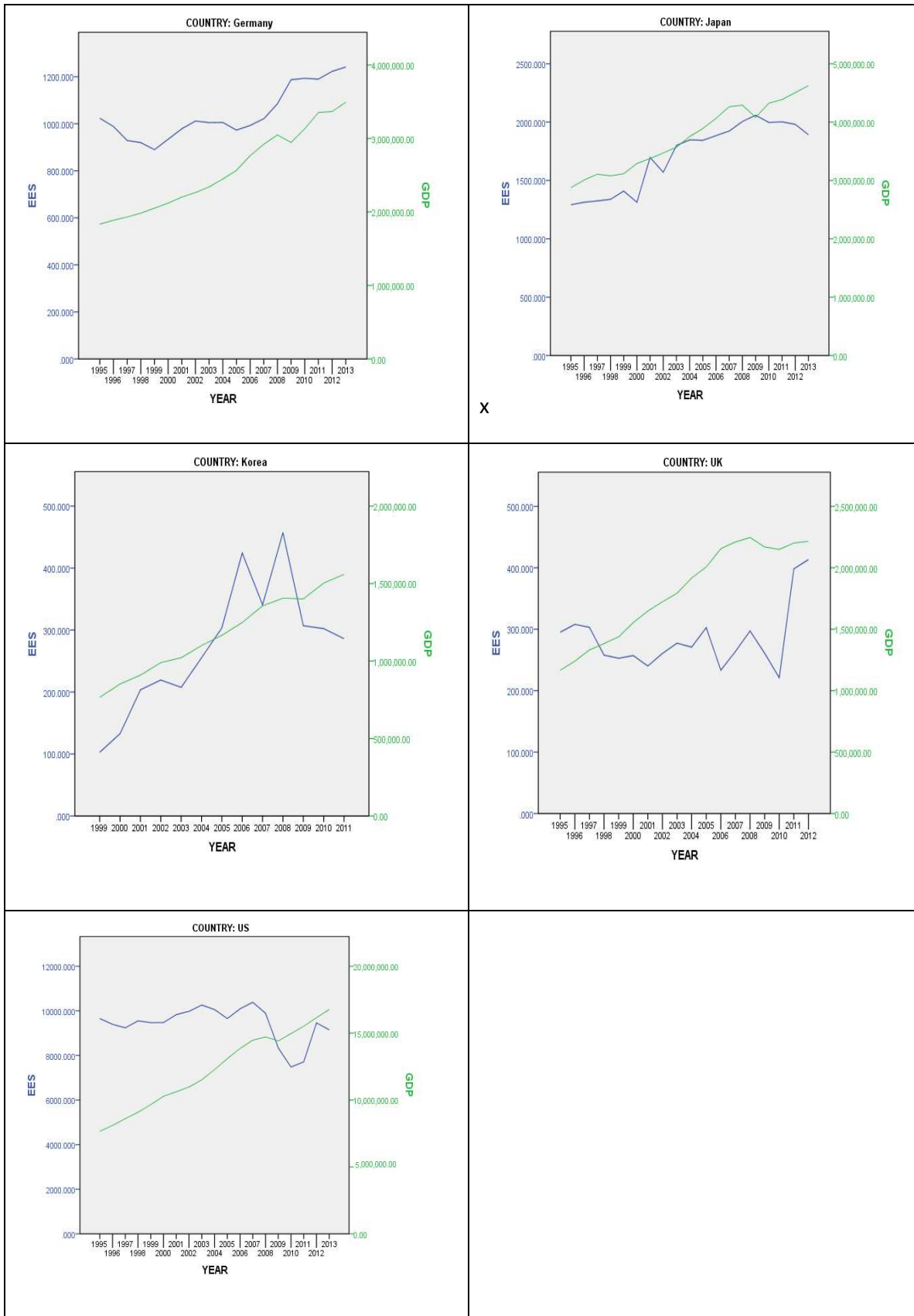
[Chart 1] Government Expenditure on R&D on Space and Earth.

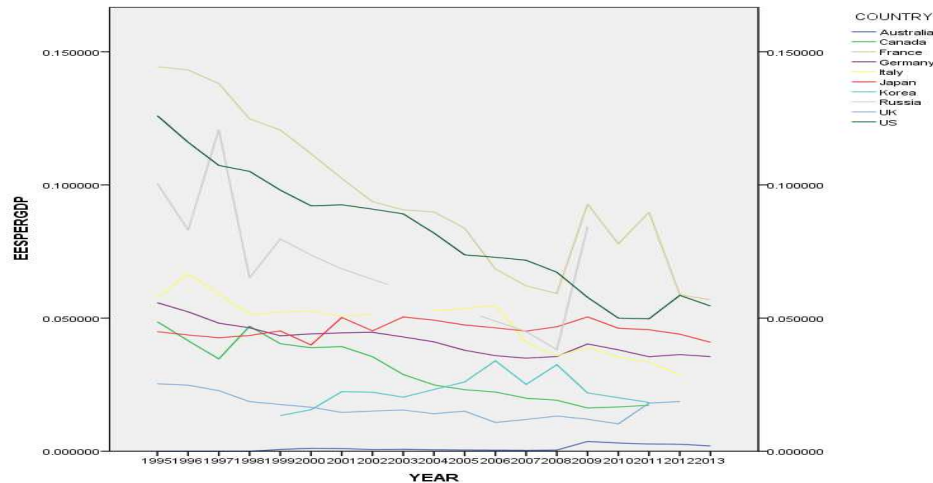
**Legend:**

EEE: Expenditure in exploration and exploitation of the Earth (million 2005 dollars)  
 EES: Expenditure in Exploration and exploration of Space (million 2005 dollars)  
 $EEEEPERGDP = EEE / GDP\%$   
 $EESPERGDP = EES / GDP\%$   
 $TOTAL = EEE + EES$









The above graphs and analysis indicate that different countries have rather different trends. When the EES is presented as a percentage of GDP, the percentage steadily decreases over time, with the exception of Japan and the Republic of Korea. Japan's percentage of expenditure has maintained a steady state while the Republic of Korea has been increasing its expenditure in space exploration and exploitation faster than its annual GDP is growing. Interestingly, the financial crisis in 2008 did not have significant impact on any major space investors. Moreover, while the United States, the United Kingdom, and Republic of Korea dramatically decreased their space budget, there were no noticeable changes in the space budget of other countries. France actually increased its space budget significantly. The following two factors might explain the limited impact of the financial crisis on space budget: 1) except for the United States, the relative and absolute size of the space budget is too small to be affected by the crisis; and 2) the space budget is managed under a long-term financial cycle, which is not affected by short-term changes in the economic situation.

In terms of developing countries, the charts on annual trends only show the investment of major economies and do not show that of developing countries. In fact, it was almost impossible to find reliable data on developing countries' space expenditure. It might be due to lack of investment and/or a lack of data collection.

Research on the general trends of investment in space and Earth observations of developing countries shows that ASEAN nations are starting to invest more in building space programs. In 2014, Viet Nam launched its first remote sensing satellite to monitor natural resources and disasters with cooperation and funding from France. Also, in late 2012, a bill was filed in the Philippine Congress advocating the use of science and technology for economic development, paving the way for the formation of the Philippine Space Agency (SciDevNet, 2013).<sup>4</sup>

Euroconsult, a space market consultancy firm, released figures of ASEAN investments in civil space programs in 2012 and showed that Viet Nam was the largest

<sup>4</sup> As of January 2015, the bill has not been passed yet.

spender among this group with US\$93 million, followed by Lao People's Democratic Republic (US\$87 million), Indonesia (US\$38 million), Thailand (US\$20 million) and Malaysia (US\$18 million). Indonesia, Malaysia and Thailand have advanced space agencies of their own, while Lao People's Democratic Republic, one of the poorest ASEAN members, now has the second largest budget on space programmes in the region (SciDevNet, 2013).

## **6. KEY FINDINGS AND LESSONS LEARNED**

Drawn from analysis of existing literature and activities, key findings and lessons learnt here are drafted primarily in reference to developing countries in the region, and are less applicable for developed countries.

### **6.1 Locked Benefits from Space Technology Applications**

The analysis shows that space utilization and space-derived information have acted both as an enabler and as a catalyst for countries' efforts in progressing towards internationally agreed development goals (MDGs) and the post-2015 development agenda (SDGs). Space technology applications have emerged as effective and innovative tools to support the implementation of mechanisms to realize both MDGs and SDGs. They have contributed to the productivity and efficiency of (1) sustainable economic growth and poverty reduction by providing essential information and guidance; (2) sustainable urban development by creating an urban inventory, thematic maps, and queries for identifying most vulnerable urban areas; (3) improved decision making by providing scientific proof for climate change impact and mitigation measures in inaccessible areas; and (4) assisted in meeting the basic needs of MDGs such as resource management, transportation, agriculture and disaster risk management. Furthermore, space technology applications and geospatial information such as tele-medicine are indispensable in the fight against infant and maternal mortality, malaria, HIV/AIDS and other diseases of the MDGs. Tele-education targeting women can also bring high quality educational opportunities to uneducated women and children in even the most remote of villages and potentially enhance employment prospects for female professionals.

However, these potential benefits have yet to reach developing countries. It is challenging to locate good practices regarding applications of space technology and GIS in the documents and research papers from developing countries. Thus, there is a growing concern regarding the widening capacity gap in space technology as well as space-derived data and information between developed and developing countries. Even with current efforts to develop technological and scientific methodologies to exploit and share space observations, the existing capacity gap continues to slow down collaboration and coordination. The lack of scientific data and the inability to analyze the available data also represents a significant challenge. Bridging the gaps by making valuable data available to developing countries and forging stronger collaborations is seen as a way to aid developing countries build local capacities. The cost of capacity building (processing and analyzing data), however, is often very high for developing countries (Barbiere,

2013). Much of the progress that has been made thus far in reducing the disparity between countries has been achieved through regional cooperation mechanisms where nations with high capacity share their knowledge with countries with limited capacity in the name of elevating the Asia-Pacific region as a whole.

## **6.2 Weak Geospatial Data Infrastructure**

One of key challenges in identifying the current status and trends of good practices and investment related to space technology applications of developing countries in the Asia-Pacific region is lack of data. This lack of data includes inaccessible government expenditure and investment reports for space-related research and activities as well as limited academic documents (such as good practice and research papers by universities). Not having said data to analyze makes it inherently difficult to identify a clear picture of the overall progress made so far and pinpoint persistent challenges in utilizing space technology for sustainable development in developing countries.

It is also difficult to obtain data for National Geospatial Data Infrastructures (NGDIs) or National Spatial Data Infrastructures (NSDIs). NGDI is defined as “[a] collaborative network of system and human actors that exploit contributed data and computational resources, many of which are spatially explicit, for one or more targeted objectives, making use of service offerings and consumptions” (de By, Lemmens, & Morales, 2009). This data is critical because by definition, NGDIs enable collaborative efforts because they are in place to support the facilitation of geospatial data-sharing and access.

At the core of GDIs is spatially contributed data which is issued through a collaborative network. Data sharing among countries within the same region will technically be faster and easier with data sharing mediums such as geoportals. However, very few of countries in the Asia-Pacific region have either developed/operational or in-development NSDIs (NSDIs are a necessary pre-requisite for an efficient geoportal).

Geoportals are at the forefront of Geospatial Data Infrastructures (GDIs.) With the exception of Indonesia and the Philippines, most developing countries in the region do not have operational portals. The establishment of a NSDI will require every agency in the nation, at both its central and its local levels, to have an established ICT structure for the geoportal. Information from various different governments must be added to the geoportal in order to provide the most robust information set possible. Establishing a geoportal therefore also requires the government to set modernized standards for geospatial datasets. Currently, few countries in the Asia-Pacific region have established standards for space-derived geospatial datasets. These countries adopt, only as a manner of convention, the standards used by developed countries (Tupas, Sarmiento, Blanco, & Bangate, 2012).

Against this background, ESCAP has initiated and supported member States in the development of national geoportals in selected developing countries with a pilot regional geoportal project named “The Community of Practices.” “The Community of

Practices” was established to facilitate the sharing of geospatial data through the implementation of a United Nations development account project from 2011-2014. As a result, national geoportals in Fiji, Mongolia, Nepal, and the Cook Islands were established along with the provision of capacity-building on how to establish, operate and manage a geoportal.

### **6.3 Lack of Financial Mechanisms and Investment in Space Technology Applications**

Investing in space-related technology and infrastructure requires significant financial resources and human resources. The Asia-Pacific region has one of the world’s most dynamic financial environments. Projections show that the region will continue to grow in part due to the financial policy reforms of the Asian financial crisis.

The available financial resources for investment in space technology applications and infrastructure depend largely on the country’s economic performance and whether or not those resources are being managed efficiently.

A recent analysis of the average investment trends in OECD member countries showed the contraction or constant in government budget expenditure over the last decades (practical contraction), in terms of total government expenditure in exploration and exploitation of Earth and Space among GDP as seen in the analysis<sup>5</sup>. However, the scale and range of internal and international financial mechanisms has yet to be fully explored and made concrete in developing countries. It is difficult to find clear financial mechanisms and investment plans for space-related infrastructures and technologies in the developing countries of the region. Further research and studies are recommended to continue to identify overall trends of finance-related challenges.

In this regard, it is advisable for international and regional organizations to step up their efforts to build financial mechanisms including national budget systems to promote space technology applications and geospatial information infrastructure so that developing countries can take full advantage of all of the benefits space applications can offer towards sustainable development. Furthermore, as a mid-term plan, it is recommended that regional financing organizations, such as the Asian Development Bank, provide the seed money required in order to promote the implementation of a regional geospatial data infrastructure.

### **6.4 Limited Exchange of Geospatial Data**

According to our analytical study, recognition of the benefits of space utilization and exploration is growing in the context of addressing many development challenges. However, the findings also show that most of the developing countries do not have access to full services and products from space-related activities and programmes. One of the major reasons for this is insufficient sharing infrastructure and systems for near-real-time

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<sup>5</sup> Source: OECD stats.

geospatial data at both country and regional levels. Unavailability of data leads to inadequate planning and ineffective implementation in socio-economic activities. There is an urgent need to share geospatial data and socio-economic data among Ministries and countries through targeted policies and efficient cooperative frameworks.

Many sustainable development challenges such as trans-boundary river management, the Asia-Pacific Super Highway, environmental pollution, climate change impact, and regional disaster management (such as tsunami preparedness) go beyond the political and territorial boundaries of a single country. Even if an individual country possesses their own space-derived information and infrastructure, it can still benefit from well-established regional and international cooperation mechanisms through sharing good policies, expertise and practices, strengthening capacity-building, conducting regional/sub-regional joint training programmes, and carrying out joint actions on regional disasters in areas of particular mutual interest. This is not to mention that the establishment of regional and international cooperation mechanisms make for a mutually beneficial scenario where countries are better able to communicate and cooperate with each other, leading to better facilitation in areas such as trade and investment.

Towards this end, there are growing cooperative mechanisms and frameworks for international and regional cooperation regarding the use of space technology for sustainable development. Currently UN-GGIM, United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOS), UNOOSA, UN-SPIDER, and the International Strategy for Disaster Reduction (UNISDR) are global cooperation mechanisms, which carry the United Nations mandate and responsibility for promoting international collaboration on the applications of space technology in the areas of disaster risk reduction and sustainable development. In the Asia-Pacific region, the Space Applications Programme for Sustainable Development for Asia and the Pacific (RESAP), AP GGIM, Sentinel Asia, and APRSAF are key facilitators.

However, despite the good progress made by United Nations agencies and regional organizations, the current achievements remain far below the technology's potential. The ultimate goal would include implementing a system to facilitate efficient sharing of data between advanced countries with mature space-derived data and gathering systems and less developed countries with low capacity. For example, increased regional engagement in the Open Data Sharing Initiative and the establishment of a region-wide, standardized system for sharing space-derived datasets are not yet ensured. Government partnerships with academia, university and the private sector still require significant strengthening towards a comprehensive network to support their intelligence.

Put succinctly, it is imperative to implement a regional policy and cooperative framework to facilitate the sharing of high quality geospatial data at affordable prices, in an important step towards improving sustainable development. In addition, governments should strengthen national policies directed specifically at implementing space-derived technologies in efforts to link national regions and improve infrastructure efficiency in transportation and industrial development sectors.

In particular, increased regional engagement and support for the Open Data Initiative and the establishment of a region-wide, standardized geospatial data infrastructure (GDI) for sharing space-derived datasets will ensure properly organized, rapid and coordinated transmission of information from regional partners to the country in need. This is an area of cooperation that needs to be developed in the immediate future.

In parallel with open data policy, it is necessary to promote sharing best practices and ideas through professional networks: for example by inviting experts from developed countries to developing countries to share the latest in scientific research. This method of information exchange creates a strong network of professionals and increases the possibilities for collaboration between countries and regions.

## **6.5 Widening Digital Gaps in Space-derived Data and Products**

Despite growing recognition for the benefits of space technology and GIS applications, given the lag the developing nations are experiencing in achieving the MDGs there is still a perception that investment in space science and technology is of low priority. Low government investment in research and development (R&D) for space programmes and GDIs may be a main cause for the widening digital gap between developed countries and developing countries, including the capacity gap to build, operate and manage GDIs. Ironically, it is actually the lack of geospatial data and the inability to combine the available data that has posed a significant challenge in achieving MDGs and SDGs.

In addressing the growing digital gaps in space-derived data and products, the regional framework to access and use geospatial data and facilities should be further strengthened, in a conscious shift away from the release of space data by advanced countries on an ad hoc basis. Bridging the gaps by making valuable data available to developing countries and forging stronger collaborations is one way to aid developing countries build local capacities.

The seamless coordination among member States including sharing of space-derived data as well as socio-economic data is a sustainable development strategy in itself. The strategy also includes successfully involving non-governmental entities in on-going studies to assess end-user requirements and measure the practical commercial and industrial implementation of spin-offs of space technology, and the economic importance of spillovers from the space sector and in various projects regarding the assessment of end-user requirements.

The institutional arrangements include possible legislation at the national and regional levels, such as the law on promotion of space technology for sustainable development or the law on government investment in research on space technology. These laws offer the opportunity to promote the introduction, implementation, monitoring and accountability (United Nations Office for Disaster Risk Reduction, 2013), of space technology to ensure easy access to important information for both experts and ordinary

citizens alike. The legal frameworks by institutional arrangement provide financial and procedural support for the applications of space technology in the interest of achieving long-term goals. Legislation also facilitates diverse stakeholders cooperating in the concerted efforts for sustainable development.

## **6.6 Knowledge and Capacity Building for the Operation and Management of Space Technology Applications**

The findings highlight that most developing countries in the Asia-Pacific region do not currently have the knowledge or capacity for utilizing space-based data and products. There is a need for extracted information from the massive amount of available geospatial data, but only a few countries have the capacity to process and use the extracted information effectively. Translating the space-based language native to the data into something more palatable that a non-expert or policy maker can immediately understand and use is a substantial challenge. This challenge is fueled by the complexity of the theories and principles surrounding space technology and Earth observation.

In establishing this connection, the first important measure is (1) to strengthen knowledge such as transformation from foundational concepts and principles towards the operationalization of space-derived products. Strengthening knowledge also includes the need to manage the facilities to maximize the benefits from the operation of geospatial data infrastructure and applications in sustainable development sectors; and (2) to enhance technical knowhow and capacity on the mechanical study of software and procedures. For example, the capacity to use GIS software to generate hazard maps from digital maps and data.

In order to maximize the benefits of space-based information and products, the capacity to cooperate and collaborate with partner agencies and stakeholders is required not just between United Nations agencies but also between research institutes, academia and universities, and not only within the governments and ministries in the countries themselves but also in agencies at the regional level. In this regard, it should be noted that many developing countries are relatively weak in managing cooperative partnerships with civil society and research institutes in developing strategies and implementation, etc., including responsive data sharing mechanisms between government agencies and relevant sectors of society.

Seeing that space technology evolves at such a rapid rate, it is essential to continuously invest in capacity building for new technology. There is a need to look into the inclusion of the use of modern geospatial information technologies in the development of policies for decision support systems. It is recommended that continual review of the policies involving space technology for sustainable development be done on both national and local levels.



## 7. Conclusion

In terms of advancement of its capabilities and an increase in usage, space technology and GIS applications have made significant progress. Since recognition of the gap between capability and usage in the 1990s, organizations have actively launched programs to bridge the gap between providers and end-users. The outcome document of the United Nations Conference on Sustainable Development, entitled “The Future We Want” (General Assembly resolution 66/288) acknowledged the importance of space-technology-based data, in situ monitoring and reliable geospatial information for sustainable development policymaking, programming and project operations. In combination with ground information sources, space technology applications such as remote sensing are essential for improving the global understanding of terrestrial, oceanic and climate-related parameters to aid in ensuring sustainable development.

However, despite the enormous potential benefits from utilizing space-derived products in key development sectors, the overall investment in space technology and GIS is still limited in developing countries. Many advanced countries have reduced or merely maintained the previous levels of their R&D budget in space and Earth observation. Considering the increasing GDP, constant budget allocations mean practical contraction of government expenditure.

Documentation of geospatial data, good practices and systems including government expenditure on R&D in space and Earth observation is severely lacking. Many developing countries such as the Philippines have not yet established a space agency, and thus systematic statistics and documentation related to space and Earth observation programmes and activities are not easily found.

Space-derived data and technology provide essential information and guidance for productivity and efficiency of industry and market, creation of employment opportunities, urban planning and infrastructure, deforestation, precision agriculture practices, climate change impact and early warning systems, and disaster risk management. For example, creating an urban inventory, thematic maps, and queries also help to identify the most vulnerable urban areas and "what-if" scenarios that aid in sustainable urban planning and climate mitigation measures.

Even if a country has their own space-derived information and infrastructure, the country can still benefit from well-established regional and international cooperation mechanisms through sharing good policies, expertise and practices, strengthening capacity-building, conducting regional/sub-regional joint training programmes, and carrying out joint actions on regional disasters in an area of particular mutual interest.

The Indian Ocean Tsunami in 2004 directly affected more than nine countries including Indonesia, India, Sri Lanka and Thailand. The disaster led to the establishment of regional cooperation mechanisms and organizations for geospatial data sharing and coordinated actions such as ESCAP Tsunami Trust Fund and RIMES. These agencies work to help the region address disaster risk more effectively.

The study also exposes emerging challenges in promoting the use of space technology and GIS. Simultaneously, the study also reveals the maximum benefits possible with the optimal use of these space-derived technologies and knowledge.

Building National Geospatial Data Infrastructures (NGDIs) and Regional Geospatial Data Infrastructures such as Geoportals is a matter of the highest priority. The ability to produce geospatial data in a more systematic manner is absolutely key. NGDIs make it easier for regional stakeholders to work together to increase geospatial data-sharing and access. Furthermore, NGDIs promote regional cooperation on regional common challenges such as climate change and regional disasters.

Despite noticeable progress in using space technology and GIS, there is still significant need in developing countries to enhance institutional arrangements and build capacity in space technology applications and operation. To ensure the success, sustainability and continuity of a sustainable development strategy, the region must form a strong link to political, legal and institutional building, as well as commit to integrated efforts of central and provincial governments. Well integrated institutions on the use of space technology applications can provide the basis on seamless sharing and coordination of geospatial datasets beneficial to wide sectors of sustainable development.

A specific challenge identified in institution building is the unbalanced allocation of space and GIS specialists. With regard to capacity building, the most important capacity of government officials is to manage and coordinate the sharing and exchanging geospatial data among diverse relevant agencies and stakeholders such as government agencies, regional organizations, research institutes, academia and universities. The coordination of data exchange is imperative to maximize the benefits of space-based information and products.

Currently many United Nations agencies such as UN-GGIM, UNOOSA, UNISDR, UNESCAP, RESAP, Sentinel Asia, and APRSAF, etc., are actively working in the region. Despite great contributions and achievements by these organizations, there is still notable room for improvement. For example, increased regional engagement in the Open Data Sharing Initiative and the establishment of a region-wide, standardized system for sharing space-derived datasets is yet to be realized. In addition, partnerships with academia, university and the private business sector must be strengthened in order to manage the intelligence of space technology collectively.

In conclusion, space activities are having an ever growing influence on society, culture, the economy and the environment around the world; they are becoming a key tool in sustainable development. Space-derived information system and space technology applications are actually essential in ensuring sustainable development. However, for many developing countries in Asia and the Pacific, there remain many obstacles to participating in space activities and reaping their benefits.

In order to promote sustainable space utilization and exploration, member States in the region should fortify space cooperation in the region as soon as possible. United Nations agencies and regional organizations should also support the developing countries with the priority on (1) building geospatial data infrastructure including geo-portals, and standardization of geospatial datasets for the easy exchange of geospatial data, (2) building regional financial mechanism to support investment in the space/Earth observation technologies and capacities, establishment of geospatial data infrastructure, and (3) supporting institutional arrangements and capacity building along with fostering partnerships with civil society, universities and academia at both regional and national levels.

## References

- Adams, S., & Friedland, C. (2011). A survey of unmanned aerial vehicle (UAV) usage for imagery collection in disaster research and management, 9<sup>th</sup> international workshop on ..... Retrieved from [http://blume.stanford.edu/sites/default/files/RS\\_Adams\\_Survey\\_paper\\_0.pdf](http://blume.stanford.edu/sites/default/files/RS_Adams_Survey_paper_0.pdf).
- Apaydin, O. & Gonullu, M.T. (2007). Route optimization for solid waste collection: Trabzon (Turkey) case study. *Global NEST Journal*, Vol. 9, No.1, pp. 6-11, ISSN 1790-7632.
- Asia-Pacific Regional Space Agency Forum. (2010). Climate R3. APRSAF Regional Readiness Review for Key Climate Missions. Melbourne: APRSAF.
- Asia-Pacific Space Cooperation Organization. (2005). Convention Asia-Pacific Space Cooperation Organization. Beijing: Asia-Pacific Space Cooperation Organization.
- Barbiere, C. (2013). Satellite imagery goldmine to developing countries. *EurActiv*. Retrieved October 12, 2014, from <http://www.euractiv.com/development-policy/satellite-images-goldmine-develo-news-530317>
- Bock, Y. (2014). Real-time GNSS for natural hazards: Early warning and monitoring systems. IGS Workshop. Pasadena: IGS.
- Speed and Accessory Load on Idling Emissions from Heavy-Duty Diesel Truck Engines. *Journal of the Air & Waste Management Association*, Vol. 52, pp. 1026-1031, ISSN 1047-3289
- Brunner, P., Hendricks-Franssen, H. J., Kgotlhang, L., Bauer-Gottwein, P., & Kinzelbach, W. (2007). How can remote sensing contribute in groundwater modeling? *Hydrogeology*, 15:5-18.
- Cashion, J., Lakshmi, V., Bosch, D., & Jackson, T. J. (2005). Microwave remote sensing of soil moisture: evaluation of the TRMM microwave imager (TMI) satellite for the Little River Watershed Tifton, Georgia. *Journal of Hydrology*, 307(1):242-253.
- Chalkias, C. & Lasaridi, K. (2009). A GIS based model for the optimisation of municipal solid waste collection: The case study of Nikea, Athens, Greece. *WSEAS*

Transactions on Environment and Development, Vol. 5, No. 10, pp. 640-650, ISSN 1790-5079

- DigitalGlobe. (n.a.). DigitalGlobe satellite imagery aids WWF in habitat preservation study. Retrieved October 13, 2014, from DigitalGlobe Corporate Website: [http://www.digitalglobe.com/sites/default/files/DG-WWF-CS-WEB\\_0\\_0.pdf](http://www.digitalglobe.com/sites/default/files/DG-WWF-CS-WEB_0_0.pdf)
- Eastham, J., Mpelasoka, F., Mainuddin, M., Ticehurst, C., Dyce, P., Hodgson, G., . . . Kirby, M. (2008). Mekong River Basin Water Resources Assessment: Impacts of Climate Change. CSIRO.
- Eteng, W. (2014, April 24). Space Science and Technology in Achieving Millenium Development Goals in Africa. Retrieved from Scribd: <http://www.scribd.com/doc/220048640/POTENTIALS-OF-SPACE-SCIENCE-AND-TECHNOLOGY-IN-ACHIEVING-THE-MILLENNIUM-DEVELOPMENT-GOALS-IN-AFRICA>
- European Union Community Research and Development Information Service. (2008, October 3). EU/AU partnership in science, ITC and space presents flagship projects. Retrieved October 13, 2014, from European Union Community Research and Development Information Service: [http://cordis.europa.eu/news/rcn/29936\\_en.html](http://cordis.europa.eu/news/rcn/29936_en.html)
- ESRI, GIS solutions for agricultural government, ESRI, New York, USA
- European Space Agency. (2006, February 8). Active Road Management Assisted by Satellite (ARMAS). Retrieved October 13, 2014, from ESA Navigation: [http://www.esa.int/Our\\_Activities/Navigation/Active\\_Road\\_Management\\_Assisted\\_by\\_Satellite\\_ARMAS2](http://www.esa.int/Our_Activities/Navigation/Active_Road_Management_Assisted_by_Satellite_ARMAS2)
- European Space Agency. (2014, February 15). FISHSAT - Integrated Satellite Services for Fishing Support and Safety. Retrieved October 13, 2014, from ESA ARTES Applications: <http://artes-apps.esa.int/projects/fishsat>
- FAO Regional Office for Asia and the Pacific. (1999). Code of Practice for Forest Harvesting in Asia-Pacific. Bangkok, Thailand: Food and Agriculture Organization of the United Nations Regional Office for Asia and the Pacific.
- FAO Regional Office for Asia and the Pacific. (2014, September 16). Asia and the Pacific heading to achieve MDG hunger target: remaining regional gap narrows to less than one percentage point. Retrieved September 23, 2014, from FAO Regional Office for Asia and the Pacific Website: [http://www.fao.org/asiapacific/rap/home/news/detail/en/?news\\_uid=243895](http://www.fao.org/asiapacific/rap/home/news/detail/en/?news_uid=243895)
- Global Geodetic Observing System Portal. (2011, September 16). Retrieved from IAGGOS: [http://www.ggos-portal.org/lang\\_en/GGOS-Portal/EN/Topics/Services/IGS/IGS.html](http://www.ggos-portal.org/lang_en/GGOS-Portal/EN/Topics/Services/IGS/IGS.html)
- Goodman, S. J., Laymon, C., & Meyer, P. J. (2005, April 11). Economic Benefits of Remote Sensing in Transportation: Case Studies of Environmental Analysis in Transportation Planning. Retrieved from National Consortium for Remote Sensing in Transportation - Environment: <http://www.ghcc.msfc.nasa.gov/land/ncrst/rscostbene.html>

- Guimon, J. (2014). Investing in R&D and innovation in developing countries for addressing societal challenges. 5th INCO Conference: “Addressing Future Challenges”. Athens, Greece.
- Hassan, S. (2013). Sound practices in space technology applications for disaster risk reduction and inclusive and sustainable development. Bangkok: UN ESCAP.
- Howard, A. (2011, September 19). Historic global Open Government Partnership launches in New York City. Retrieved October 13, 2014, from O'Reilly Radar: <http://radar.oreilly.com/2011/09/historic-open-government-partn.html>
- Indian Space Research Organization. (2010). ISRO Homepage. Retrieved from About ISRO: [isro.org](http://isro.org)
- Inggs, M. R., & Lord, R. T. (n.d.). Applications of Satellite Imaging Radar. Retrieved from University of Cape Town: <http://www.rsg.uct.ac.za/applications/applications.html>
- International GNSS Service. (2008). IGS Strategic Plan 2008-1012. California: IGS Central Bureau.
- International GNSS Service Central Bureau. (2014). About the IGS. Retrieved from IGSCB: <http://igsb.jpl.nasa.gov/overview/viewindex.html>
- International GNSS Service Terrestrial Frame Combination Center. (2012). Retrieved from IGN: <http://webigs.ign.fr/en/tfcc/about>
- Jiren, L., & Mancini, M. (2012). Application of remote sensing and other space technology to hydrology and water resources. Dragon2 Final Results and Dragon3 KO Symposium. Beijing: ESA-MOST.
- Kaku, K., & Held, A. (2013). Sentinel Asia: A space-based disaster management support system in the Asia-Pacific Region. *International Journal of Disaster Risk Reduction*, 1-17.
- Kanchanabhan, T.E.; Abbas Mohaideen, J.; Srinivasan, S. & Lenin Kalyana Sundaram, V. (2011). Optimum municipal solid waste collection using geographical information system (GIS) and vehicle tracking for Pallavapuram municipality. *Waste Management & Research*, Vol. 29, pp. 323-339, ISSN 1096-3669
- Karadimas, N.V.& Loumos, V.G. (2008). GIS-based modeling for the estimation of municipal solid waste generation and collection. *Waste Management & Research*, Vol. 26, pp. 337-346, ISSN 1096-3669
- Krishna Murthy, Y. N. (2014). Capacity Building for Disaster Management Support. SSTDM 2014. Bengaluru: IIRS.
- Landenberger, R., & Deagen, D. (2011). AmericaView: A National Remote Sensing Consortium - Annual Progress Report for Grant Year FY2010. USGS.
- Lopez Alvarez, J.V., Aguilar Larrucea, M., Fernandez-Carrion Quero, S., Jimenez del Valle, A. (2008). Optimizing the collection of used paper from small businesses through GIS techniques: The Legane's case (Madrid, Spain). *Waste Management*, Vol.28, No. 2, 2008, pp. 282–293, ISSN: 0956-053X

- Loveland, T., & DeFries, R. (2004). Observing and Monitoring Land Use and Land Cover Change. *Geophysical Monograph Series: Ecosystems and Land Use Change*, 153: 231-246.
- Malykhina, E. (2013, April 9). Home Is Where the Health Is: Obamacare Positions “Telehealth” Tech as a Remedy for Chronic Hospital Readmissions. Retrieved October 13, 2014, from Scientific American: <http://www.scientificamerican.com/article/affordable-care-act-technology/>
- Milewski, A., Sultan, M., Yan, E., Becker, R., & Abdeldayem, A. (2009). A remote sensing solution for estimating runoff and recharge in arid environments. *Journal of Hydrology*, 373(1):1-14.
- National Aeronautics and Space Administration. (2010). *US Space Programme Spin-off*. Washington D.C.: NASA.
- Nichol, J. E. (1996), High-Resolution Surface Temperature Patterns Related to Urban Morphology in a Tropical City: A Satellite-Based Study. *Journal of Applied Meteorology*, 35(1) 135-146.
- Noichim, Chukeat. (2008), Promoting ASEAN space cooperation, *Space Policy* 24 (2008) 10-12, ScienceDirect.
- Noll, T. E., Brown, J. M., Perez-davis, M. E., Ishmael, S. D., Tiffany, G. C., & Gaier, M. (2004). *Investigation of the Helios Prototype Aircraft Mishap Volume I (Vol. I)*.
- Nuortio T., Kytöjokib J., Niska H., Bräysy O. (2006). Improved route planning and scheduling of waste collection and transport. *Expert Systems with Applications*, Vol. 30, No. 2, February 2006, pp. 223-232, ISSN: 0957-4174
- Parida, R. B., & Oinam, B. (2008). Drought Monitoring in India and the Philippines with Satellite Remote Sensing Instruments. *EARSeL eProceedings* 7, (pp. 81-91).
- Parker, S. (2011). *Civic Engagement and Disability: using advocacy and technology to advance the political participation of people with disabilities*. Institute for Policy and Civic Engagement, College of Urban Planning and Public Affairs. Chicago: University of Illinois at Chicago.
- Pereira, R. A., & Lopez, E. D. (2004). Characterizing the Spatial Pattern Changes of Urban Heat Islands in Metro Manila Using Remote Sensing Techniques. *Philippine Engineering Journal*, 25(1): 15-34.
- Regional Integrated Multi-Hazard Early Warning System for Africa and Asia. (2014, August 15). *RIMES Overview*. Retrieved from Regional Integrated Multi-Hazard Early Warning System for Africa and Asia: [http://www.rimes.int/about\\_overview.php](http://www.rimes.int/about_overview.php)
- Roychowdhury, K. (2014). India and the Millenium Development Goals (MDGs): Modelling health and development from satellite images at the subnational level. 7th International Congress of Environmental Modelling and Software. San Diego, California, USA.
- Organisation for Economic Co-operation and Development (2014), *The Space Economy at a Glance 2014*, Paris, France

- Organisation for Economic Co-operation and Development. (2013). The Space Economy at a Glance 2013, Paris France
- Organisation for Economic Co-operation and Development (2014), Statistics,
- Samiento, Czar (2014), Contributions and challenges of space technology applications to disaster risk reduction and sustainable development in the context of the post-2015 development agenda, Philippines
- Sarmiento, C. S., Gonzalez, R. M., & Castro, P. M. (2012). Remote Sensing and GIS in Inflow Estimation for Reservoir Operations: Magat Dam, Philippines. Remote Sensing and Hydrology, 325-328.
- Saradeth, S., Dodo, A. K., & Latrech, D. (2010). Earth Observation in support of Management of Internationally Shared Groundwater Resources in Africa: the AQUIFER Project. In UNESCO-IHP, Application of satellite remote sensing to support water resources management in Africa: Results from the TIGER Initiative (pp. 1-14). Paris, France: International Hydrological Programme of the United Nations Educational, Scientific and Cultural Organization.
- Sahoo, S., Kim, S., Kim, B-I., Kraas, B., Popov, A. (2005). Routing Optimization for Waste Management. Interfaces, Vol. 35, No. 1, January 2005, pp. 24-36, ISSN: 0092-2102
- SciDevNet. (2013, March 27). How Science got a Voice in the Philippine Congress. Retrieved from SciDevNet: <http://www.scidev.net/global/feature/how-science-got-a-voice-in-the-philippine-congress-1.html>
- SciDevNet. (2013, May 16). Is Asian Space Science Drive Harming Development. Retrieved from SciDevNet: <http://www.scidev.net/global/climate-change/feature/is-asian-space-science-drive-harming-development--2.html>
- Someswar, G. M., Chandra, T. S., Dhanunjaya, R., & Chigurukota. (n.d.). Global Navigation Satellite Systems and their Applications.
- Shujing Yang, 2014, City Expansion and Disaster Management in Asia Pacific, Intern, ESCAP
- Tang Z, Engel BA, Lim KJ, Pijanowski BC, Harbor J (2005). Minimizing The Impact of Urbanization on Long Term Runoff (Paper No. 040103). J. Am. Water Resour. Association. [https://engineering.purdue.edu/ABE/People/.../minimizing .pdf](https://engineering.purdue.edu/ABE/People/.../minimizing.pdf) - United States
- Technical University of Denmark. (2009, February 27). New Oil Deposits Can Be Identified Through Satellite Images. Retrieved October 13, 2014, from ScienceDaily: <http://www.sciencedaily.com/releases/2009/02/090226110812.htm>
- Verburg, P., Kok, K., & Veldkamp, T. (2007). Integrated assessment of the land system: the future of land use. Land Use Policy, 24(3): 517-610.
- VTT Technical Research Center. (2014). Remote sensing and environment information systems. Retrieved from VTT Technology for Business: [http://www.vtt.fi/research/technology/remote\\_sensing\\_and\\_environment\\_information\\_systems.jsp?lang=en](http://www.vtt.fi/research/technology/remote_sensing_and_environment_information_systems.jsp?lang=en)

- United Nations Office for Disaster Risk Reduction. (n.a.). 13 October 2014 - International Day for Disaster Risk Reduction. Retrieved September 23, 2014, from The United Nations Office for Disaster Risk Reduction:  
<http://www.unisdr.org/2014/iddr/#.VCGInhagQl8>
- United Nations. (1945). Charter of the United Nations. New York: United Nations. Retrieved from United Nations.
- United Nations. (2012). Resolution adopted by the General Assembly on 27 July 2012. Retrieved from un.org:  
[http://www.un.org/ga/search/view\\_doc.asp?symbol=A/RES/66/288&Lang=E](http://www.un.org/ga/search/view_doc.asp?symbol=A/RES/66/288&Lang=E)
- United Nations Economic and Social Commission for Asia and the Pacific. (2012, December 24). Asia-Pacific adopts five year plan of action for the application of space technology for disaster risk reduction and sustainable development. Retrieved from United Nations Economic and Social Commission for Asia and the Pacific:  
<http://www.unescap.org/news/asia-pacific-adopts-five-year-plan-action-application-space-technology-disaster-risk-reduction>
- United Nations Economic and Social Commission for Asia and the Pacific. (2013). Statistical Yearbook for Asia and the Pacific 2013. Bangkok: United Nations.
- United Nations Economic and Social Commission for Asia and the Pacific. (2014). DA7: Expert Group Meeting (EGM) on Geo-referenced Information Systems for Disaster Risk Management (Geo-DRM) and Sustaining the Community of Practice (COP). Bangkok, Thailand: UN ESCAP.
- United Nations Economic and Social Commission for Asia and the Pacific. (2014). Regional Cooperation in Space Applications. Retrieved from unescap.org:  
<http://www.unescap.org/our-work/ict-disaster-risk-reduction/space-technologies-and-gis-applications-sustainable-development/about>
- United Nations Economic and Social Commission for Asia and the Pacific. (2014, March). Regional Cooperative Mechanism for Drought Monitoring and Early Warning in Asia and the Pacific (The Drought Mechanism). Bangkok, Thailand.
- United Nations Economic and Social Commission for Asia and the Pacific. (2014). Resolution 69/11: Implementation of the Asia-Pacific Plan of Action for Applications of Space Technology and Geographic Information Systems for Disaster Risk Reduction and Sustainable Development, 2012-2017. Bangkok: United Nations.
- United Nations Economic and Social Commission for the Asia Pacific. (2010). Jakarta Declaration on Public-Private Partnerships for Infrastructure Development in Asia and the Pacific. Asia-Pacific Ministerial Conference on Public-Private Partnerships. Jakarta: United Nations.
- United Nations Economic and Social Council. (2004). Promoting the application of science and technology to meet the Development Goals contained in the Millennium Declaration. Geneva: UN ECOSOC.
- United Nations Committee on the Peaceful Uses of Outer Space. (June 2014). Report of the Committee on the Peaceful Use of Outer Space (57<sup>th</sup> session), New York.



- United Nations, Report of Secretary-General, the 17th session of the Commission on Science and Technology for Development, Geneva, 12-16 May 2014 (E/cn.16/2014/2)
- UN Open Working Group on Sustainable Development Goals. (2014, July 19). Introduction to the Proposal of The Open Working Group for Sustainable Development Goals. Retrieved October 11, 2014, from United Nations Sustainable Development Knowledge Platform:  
[http://sustainabledevelopment.un.org/content/documents/4518SDGs\\_FINAL\\_Proposal%20of%20OWG\\_19%20July%20at%201320hrsver3.pdf](http://sustainabledevelopment.un.org/content/documents/4518SDGs_FINAL_Proposal%20of%20OWG_19%20July%20at%201320hrsver3.pdf)
- United Nations OCHA. (2014). Unmanned Aerial Vehicles in Humanitarian Response.
- Orhan Altan, (October 2009), Geospatial Technologies to Reach the Millennium Development Goals, the 18<sup>th</sup> UN Regional Cartographic Conference for Asia and the Pacific
- Wagner, W., Verhoest, N. C., Ludwig, R., & Tedesco, M. (2009). Remote Sensing in Hydrological Sciences. *Hydrology and Earth Systems*, 13: 813-817.
- Walker, M. (2009). APEC Promoting Global Navigation Satellite Systems Applications. Washington D.C.: National Coordination Office for Space-Based Positioning, Navigation, and Timing.
- Warner, J. (2007). Multi-stakeholder platforms for integrated water management. Surrey: Ashgate Publishing.
- World Bank. (2005). Natural Disaster Risk Management In The Philippines: Enhancing Poverty Alleviation Through Disaster Reduction. World Bank and the National Disaster Coordinating Council.
- World Bank. (2010). World Development Indicators Database. Retrieved from <http://data.worldbank.org>.
- World Bank, 2010, <http://data.worldbank.org/data-catalog/world-development-indicators>
- Xu, X., & Min, X. (2013). Quantifying spatiotemporal patterns of urban expansion in China using remote sensing data. *Cities*, 35 104-113.