Digital and Space-Based Technologies for Climate Change Adaptation and Resilience

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Abstract

Digital technologies when integrated with spatial technologies have started play an important part in tackling the climate change adaptation and disaster resilience. This paper provides the status of digital technologies and applications, and their potential benefits based on past practices in Asia and the Pacific. It includes information about what combination of technologies were applied and how they contribute to the climate change and resilience by key issues. But there is necessity of transborder mechanisms to deliver digital and space-based technology providers and data users in disaster-affected areas, with the support of international activities. Public–private partnerships enable the collaborative integration of the technologies and to harness the full benefits of available applications for climate resilience. Policy makers need to explore innovative ways of building cooperative framework at regional level for upscaling digital technologies and secured data flows.

Introduction

In the past few years, industries from all corners of the globe have experienced a challenge that's unique in scale and scope. The pandemic also presented an immediate threat to business continuity, but it also served as a catalyst for rapid digital change that includes information and communication technologies and geospatial technology. Not only has this change helped businesses conquer near-term disaster risks such as the health pandemic, but it has also opened the doors to an intelligence revolution that will enable to tackle global issues such as climate change adaptation. Digital, space and geospatial technologies are no longer just fields of advanced technological development, but they have become key components to help achieve sustainable development and strengthen climate resilience. They can improve the efficiency and resilience of industrial operations.

But there is necessity of (i) transborder mechanisms to deliver geospatial and space-based information from data providers to end users in disaster-affected areas, with the support of international activities; and (ii) financial schemes involving the private sector or public–private partnerships (PPP) to enable the collaborative integration of the technologies in sustainable and practical ways. To implement such a mechanism, it is important to assess the benefits from digital and geospatial technologies and available applications, and conceptualize necessary policies.

This paper provides the status of digital technologies and applications, and their potential benefits based on past practices in Asia and the Pacific. It includes information about what combination of technologies were applied and how they contribute to the climate change adaptation and resilience by key issues, including industrial development, infrastructure planning and management, transportation management, improving quality of life, post-disaster management, improving logistics efficiency, sustainable operations of agriculture and fishery, improving efficiency manufacturing and service industry, and management of environmental services and natural resources. This paper also covers policy perspectives with strategy options about how to implement the regional connectivity supported by the technologies, especially focusing on the transborder mechanism of data and information.

Integrated digital technologies for climate resilience

Digital and geospatial technology is an intelligence technology that enables the global monitoring of a wide range of parameters such as the distribution of facilities and buildings; the movements of cars, ships, aircraft, and people; environmental change; or post-disaster economic development processes. While geospatial technology was originally developed for military and security use, it has been, in —recent years, quickly advanced as a general civil technology. It is now widely applied in the field of public services (e.g., disaster —response, social infrastructure management, traffic management), business support (e.g., marketing), and personal mobility services (e.g., navigation). The extensive use of low-cost and high-performance -mobile devices such as smartphones has further accelerated its popularization all over the world. Subsequently, the development of the Internet of Things (IoT) and Artificial Intelligence technologies have enabled researchers to conduct deeper analyses and quicker and broader information collection. In this regard, geospatial technology is expected to expand its utilization and development much further.

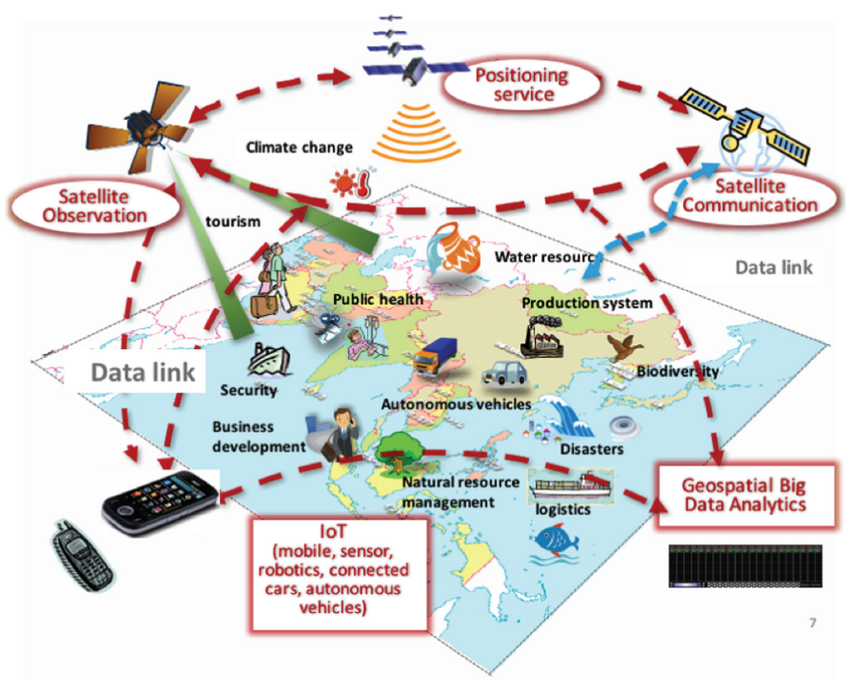
The rise of intelligence technologies resulted in the development of the following three technological areas (ERIA, 2018):

- Satellite-based earth observation technology—monitoring occurrences all over the world;
- Positioning technology—measuring and tracking precise positions in real time; and
- Communication technology—connecting almost instantly every single part of the world.

Digital and information technology provides services anywhere using dynamic information on physical, socioeconomic demographics, and environmental aspects. The technology is very naturally enhanced by space infrastructure, as illustrated in Figure 1, in a seamless manner. Therefore, the improvement in the performances of digital and space infrastructure directly leads to the climate resilience.

Integrated digital technologies could provide diverse information services using "real-world data." More concretely, the major services and contributions of the integrated digital technologies could be summarized in the following four aspects (Dobbs et al., 2013):

1. Real-time monitoring of climate information covering all land and sea such as: dynamic maps (traffic, congestion, people flow, and city changes) or environmental changes (weather, water and air quality, and greenery) from which events, accidents, and disasters can be extracted. Silent but meaningful changes such as climate change and crustal deformation can be included.
2. "Ubiquitous" data communication at any time/anywhere with small IoT devices to collect data from and send instructions/guidance to people and machines in the field.
3. Real-time localization and tracking of people, cargoes, and vehicles (air, sea, and land).
4. High-precision mapping of three-dimensional (3D) space and landscape framing activities of people and autonomous vehicles/machines, which could include very slowly moving phenomena like crust movement monitoring.



IoT = Internet of Things, SGT = Space and Geospatial Technology.

(Source: ERIA (2018))

Figure 1: Integrated digital, information and communication and space supporting climate resilience

Digital data, communication and space technologies for climate change adaptation and disaster risk management

The strong impacts of climate change disasters in the Asia-Pacific region do not simply refer to the intensity of these unfortunate events but also to the set of systemic weaknesses of Asian countries and the companies along the supply chains. One of the main reasons for the vulnerability of the Asia-Pacific region to disasters is its demography (ADB, 2013). According to the United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP), the Asia-Pacific is the most populated area in the world, with more than 4.5 billion inhabitants in 2016 (UNESCAP, 2016). The region has most of the world's largest metropolises. In 2016, the United Nations estimated that 18 of the world's 31 megacities (cities with more than 10 million inhabitants) were in Asia-Pacific and that this number is expected to reach 24 out of 41 in 2030 (UNESCAP Population Division, 2016). These high densities of population, often located around riverside flood areas, along coastlines at risk of tsunami, or at the base of landslide-prone mountains, put large numbers of human life in jeopardy due to climate change (ADB, 2016).

In its 2015 Asia-Pacific Disaster Report, the UNESCAP drew a sad portrait of the region. Between 2005 and 2014, 1,625 incidents had been reported. Most of these disasters were floods, followed, in order, by storms, earthquakes, tsunamis, and landslides. These climate disasters had a dramatic impact on the region's human security by killing almost half a million inhabitants and directly affecting the lives of approximately 1.4 billion people (see Table 1). Moreover, beyond long-term economic impact due to the loss of workforce as well as the increase in spending for health-related issues, the 1,625 disasters generated direct economic damages worth US$523 billion (UN (2016).

It is therefore primordial for the region to develop and implement ambitious climate change adaptation and disaster risk management policies and strategies based on digital technologies. The following steps describe how an integrated digital and spatial technology will contribute to climate resilience via real-time tracking, monitoring, mapping, and ubiquitous data communication capabilities:

- Monitoring and forecasting hazards at the local to regional scale, typically heavy rainfall, flooding, typhoon, drought, and tsunami, allowing governments and people to know what could happen.
- Anticipating risks or damages on human lives and economic activities by overlaying the hazard prediction on the data of people distribution/activity information, vehicle movement, and economic activity distribution/intensity.
- Mitigating damages by guiding the evacuation of people based on people distribution data and helping in the reconstruction of people's lives and economic activities.
- Improving preparedness by providing realistic simulations and trainings on DRM based on the historical records of disasters and reconstruction processes.

The capabilities described above are made possible by sharing data among governmental agencies, private industries, non-profit organizations, and people. In this regard, digital technologies and more generally data sharing can play a prominent role. It should therefore be smartly and strongly designed, not only for climate change adaptation and disaster management but for multipurpose uses, aiming at the strengthening of the regional socioeconomic environment.

As explained earlier, the potential of digital technologies incites users to go further than immediate issues like disaster by using it as an ambitious tool at all levels of the economy. It largely contributes to decision-making processes among governments, companies, communities, cities, and individuals in various contexts by providing necessary information. As digital technologies enhances the economy and facilitates "smartification" or "optimization" across various kinds of "borders," such as the border between the inside and outside of a factory, and borders among companies and regions/countries, it is extremely effective to connect all actors more tightly.

Digital technologies for enhanced climate change adaptation and resilience

Potential contributions of digital technologies for climate change mitigation

Information, such as stagnation and movement of people and vehicles, urban facilities developments, and construction of houses and infrastructures such as roads, can be continuously provided by digital. Therefore, governments and local communities can conduct proper policy making and monitoring, aiming for urban planning, urban growth management, and environmental improvement in an efficient way. For example, individual information on stagnation and movement condition of people and vehicles can be used for introducing new taxes such as congestion pricing and space use charge (OECD, 2016). Furthermore, extraction of buildings and land uses, and their changes from satellite imagery can be used for strengthening building taxation and land tax levies. To apply location information for taxation, it is necessary to implement a location authentication system to prevent spoofing.

Infrastructural conditions can be timely detected through image analysis and sensor information (Sadoff et al., 2016). Similarly, real-time supply and consumption of energy can be monitored as digital data. It will also contribute to the optimization of energy infrastructure operation and then investment, and finally lead to overall optimization. In the field of renewable energy, where fluctuations of energy production are quite dominant, more detailed and reliable data on natural environments causing fluctuations can be obtained by digital technologies, leading to the significant reduction in risks.

In the transportation system, digital technologies can track locations of vehicles, passengers, and cargoes. This will help in real-time performance monitoring of transportation systems (smoothness, efficiency, and safety). Digital technologies can easily detect problems and help continuously improve the system in combination with performance monitoring. Furthermore, automatic operation and sharing of vehicles can be performed by using real-time positioning service, which dramatically improves the efficiency and smoothness of the transportation system. It also provides the possibility to simultaneously improve uneconomical external factors such as traffic congestion, air pollution/noise, and greenhouse gas (GHG) emissions. Improvements in traffic congestion greatly contribute to the improvement of productivities (e.g., service industry) by shortening traveling time in cities. Moreover, freedom of location (houses and shops) in towns can be significantly improved, enabling city expansion and improving competitiveness. To secure the safety of automatic operation, the improvement of the security of positioning service is necessary.

Table 1: Human impact of disasters in Asia and the Pacific, 2005–2014

Disaster type	Lives lost	People affected (millions)
Earthquakes and tsunamis	199,418	74
Storms	166,762	321
Floods	43,800	771
Others	73,772	199
Total	483,752	1,366

(Source: The Asia-Pacific Disaster Report 2015, Disasters without Borders, United Nations Economic and Social Commission for Asia and the Pacific)

Better disaster response and recovery

The use of digital technologies helps quickly and exhaustively detect hazardous areas during disasters such as floods, landslides, earthquakes, and tsunamis. Therefore, evacuation can be promptly carried out in zones with high risks, leading to a substantial reduction of possible damages. Moreover, knowledge of the distribution and condition of evacuees facilitates the efficient provision of medical services and distribution of necessary items to the victims. Furthermore, a combination of information and space technologies allow the monitoring of post-disaster activities such as rebuilding or economic recovery in affected areas. The continuous and detailed assessments of disaster response and recovery activities help provide timely and appropriate support at suitable stages. Furthermore, problems can be continuously discovered and solved through the Plan-Do-Check-Act (PDCA) cycle.

More efficient and secure logistics

The use of digital technologies enables the tracking of movements of cargoes, vehicles, and ships in real time so that a reliable and continuous evaluation of transport and logistics performances can be made, leading to a significant reduction of the cost and duration of transportation. In case of climate disasters and failures, logistical delays can be forecast. Therefore, damages can be reduced by adapting the production amount and the distribution process. Moreover, damages on roads can be detected in advance, so delays and losses of logistics can be minimized by rearranging routes and transport methods. By combining trajectory analysis and location verification, deliveries of products to recipients can be confirmed, leading secure logistics without theft or illegal sales during the process. Acquiring detailed information such as routes also enables companies to better manage the quality of their products (e.g., refrigerated items and fragile objects). Furthermore, the automation of cargo handling machines during transfers from ships to trucks using secured high-precision positioning service has been developed. This contributes greatly to improving efficiency and reducing cost and time during operation, especially considering the very large geographic range of the region.

More stable, profitable, safer, and sustainable agriculture and fishery

In the agriculture industry, the use of digital technology helps in the understanding of the details of agricultural production systems, including growing processes and crop management practices. It contributes to improving agricultural operations, reducing risks of productions, and improving/stabilizing productivities and profits. More importantly, the accumulation of these data and integrating them into weather and market predictions can significantly contribute to risk reductions and production optimizations at a higher level. In addition, purchasing insurance can further reduce possible risks. Governments and agricultural market personnel can reduce agricultural impacts by controlling market fluctuations through arranging the stockpile and adjusting imports and exports based on production forecasts. Furthermore, from the viewpoint of management of land and water uses, digital technologies when combined with space technologies can contribute to the examination of proper resource uses in agriculture (cultivation, products, water use, etc.) and forestry. Thus, necessary improvements can be carried out accordingly.

In the fishery industry, the use of digital technologies enables the checking of detailed conditions of sea and fishing boat operations, the estimation of the catch amount, and the understanding of the status of fish resources and fish farm operations. This improves fishery operations and reduces risks of production and maritime accidents, leading to an improvement and stabilization of productivity and profits. Furthermore, entrance fees and charges/regulations based on resource use can be applied in the operation, leading to sustainable resource uses as well as ensuring funds for resource management. Accumulating these data and integrating them with the predictions of sea, weather, and market can largely contribute to risk reductions and production optimization. In addition, purchasing insurance can further reduce possible risks. Governments and marine products market personnel can reduce risks by controlling market fluctuations through arranging the stockpile and adjusting imports and exports based on the production forecasts. Furthermore, from the viewpoint of fishery resources and coastal environmental management, digital technologies can contribute to the examination of proper resource uses in terms of operation and coastal area utilization (water quality management, topography modification, and protection of mangroves), and its improvement, if necessary. To apply location information for developing charging systems and regulations, a location authentication system must be implemented to prevent spoofing.

More efficient manufacturing and service industries

The use of digital technologies can improve efficiency and safety in logistics, and reduce distribution cost and transportation time, leading to the reduction of production costs in the manufacture, service, and construction industries. Furthermore, allocations of production bases and branches will be flexible. As a result, unbundling of production, distribution, and consumption will be further promoted. Especially in the construction industry, uncertainties in procuring materials, equipment, and labor force will be decreased, leading to efficient process management and reduction of construction costs. As a result, arrangements in production and logistics bases will be further optimized on regional basis. Consequently, management styles, such as company size expansion, will be more flexible. Improved traffic system will also facilitate the flow of people, expand one's living area such as shopping and commuting areas, and easily attract tourists. This will lead to the expansion of the industries and the revitalization of the regional economy. The competitiveness among regional economies will be further improved.

Better quantification and management of climate services and natural resources

The development of digital technologies will enable the understanding of details in a quantitative way, including the amount and distribution of environmental services and natural resources. This helps governments and companies to more rationally conduct decision-making by considering a balance between development, use, and conservation. In addition, as the use of environmental services and natural resources can be understood, countermeasures can be immediately taken against inappropriate uses. Furthermore, introducing an appropriate payment system for environmental services further promotes its appropriate usage. This process strongly secures financial resources for environmental resources management. Thus, sustainable and adequate environmental services and use of natural resources can be achieved through system development.

Eficient use of integrated digital and space technologies

Enhanced disaster resilience

Digital technologies enable the monitoring of ongoing disasters, including how people evacuate, and the forecasting of possible situations and impacts on society. Based on information, people, communities, industries, and societies could mitigate possible damages, more easily recover from the damages, learn lessons from the past experiences recorded as digital data, and get better prepared against possible disasters. It can

- Reduce human damages by ensuring rapid information collection and delivery about disaster hazards and damages.
- Ensure goods delivery and debris removal by goods tracking and real-time recovery monitoring after disasters.
- Ensure higher accuracy of forecasts on ground/ocean weather information. Significant improvements are made using satellite earth observation. This provides industry and people with lots of social benefits.
- Secure the safety of people by improving the accuracy of monitoring and forecasting of floods, slope failure, earthquakes, and volcanic eruptions, as shown in Figure 2.
- Even after disasters, the care and consideration of vulnerable people such as babies, mothers, the aged, and injured must be provided. SGT will provide continuous monitoring capability on how the vulnerable people suffer and survive so that society can provide the necessary support in a more effective manner, as shown in Figures 2 and 3.

Enhanced multi-sector resilience

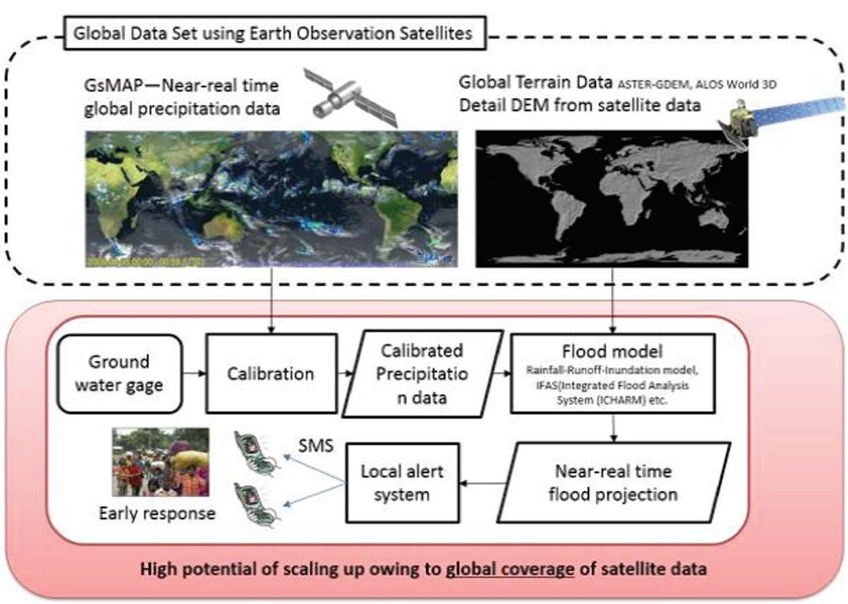
Agriculture

Agricultural production often suffers from unexpected changes in weather etc. Such environmental changes could be monitored and forecasted using digital technologies, and farmers could mitigate damages and adopt practices as illustrated in Figure 4.

- Less damages by preparing for expected typhoons and hazardous weather, as well as adjusting the timing of cropping, harvesting, shipping, and so forth.
- Optimized insurance cost by reducing agricultural risks and less compensation for agricultural damages from public sectors.

Fishery

Fishery is also very seriously affected by sea conditions. In monitoring and



ALOS = Advanced Land Observing Satellite, ASTER-GDEM = Advanced Spaceborne Thermal Emission and Reflection Radiometer-Global Digital Elevation Model, DEM = digital elevation model, GsMAP = global satellite mapping of precipitation, ICHARM = International Centre for Water Hazard and Risk Management, SGT = space and geospatial technology, SMS = short message service.

Figure 2: Flood alert system with integrated ICT and space technologies

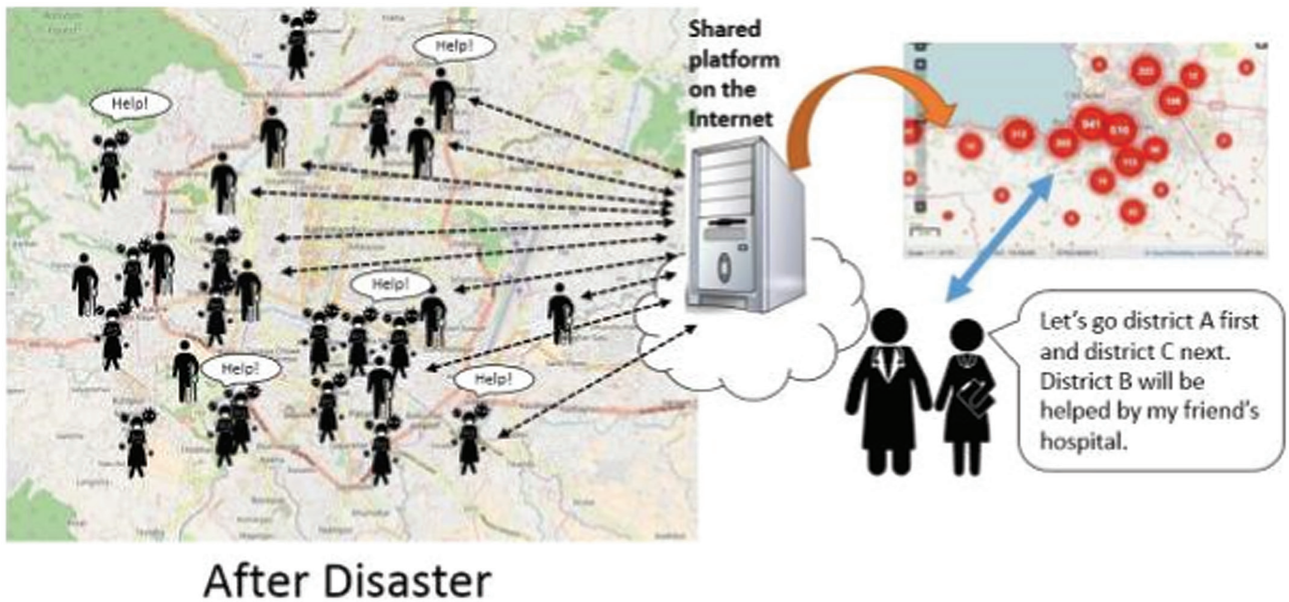
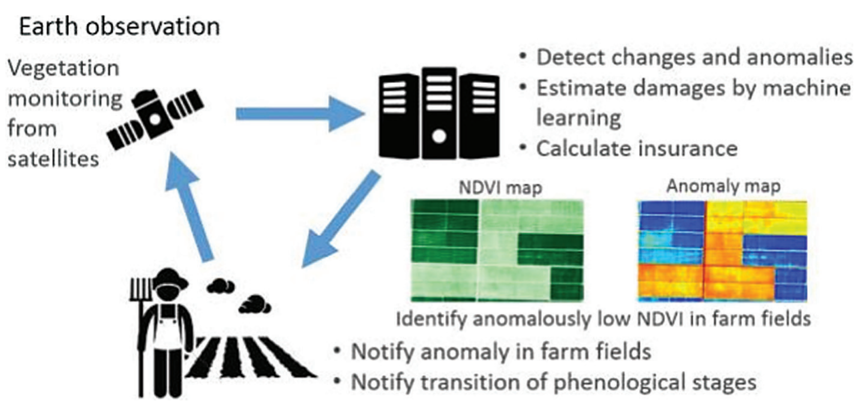


Figure 3: Supporting disaster nursing with digital technologies



NDVI = normalized difference vegetation index.

Figure 4: Application of digital technologies in agriculture sector

forecasting such conditions, risks could be mitigated. Analyzing fish catch and sea condition data enables the estimation of potential fishing ground, which leads to further risk reduction and improvement of fish catch.

- More efficient activities and operations of vessels and port facilities by forecasting harvestable areas and seasons. Better controlled market prices.
- Less impact of oceanic hazards to fishery productions by meteorological forecasting. Better security through the reduction of shipwreck.
- Better productivity and reduced risk of aquaculture production disasters through information about ocean condition and water quality (e.g., red tide).
- Management of fishery resources, securing safe operations, and detection of suspicious vessels by tracking locations and operations of vessels with verified position authentication.

Forestry

By measuring forest resources such as biomass and its distribution through the integrated digital and space technologies, the optimization of timber production could be achieved, including logging, transport, and processing.

- Ensure sustainable use of forest resources (planting, conservation, logging) by continuous monitoring of forest resources (biomass and tree types).
- Better efficiency and effectiveness in logging, lumber, and transport by quantified planning of forestry operations. Less labor hazards.
- Suppress damages of forest fire and illegal loggings.

Construction

Digital technologies will accelerate the automation of construction works through very precise real-time positioning, 3D mapping, and monitoring of environmental impacts of the works. In parallel, the process of construction will be fully digitized, which will accelerate the improvement of the construction management and technology.

- Risk reduction through effective designs and construction plans with accurately measured and shared data on terrain and geology.
- Effective management of labor and staff safety with better efficiency in transport and stock usage through continuous and accurate monitoring of things and people's position.
- Quality assurance and improvement through detection and prevention of

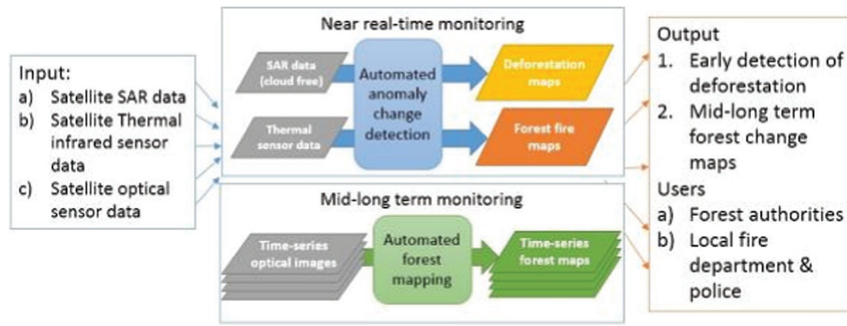
faults by accurate 3D measurement of construction progress.

Energy sector

Energy (electricity power) supply with renewable resources, typically wind, water, and solar radiation, could be estimated with digital technologies , leading to smoother matching of energy supply and demand; while energy demand could be estimated by combining multi data sources like people activity and movement monitoring, heat radiation measurement from buildings/houses, and city lights mainly from airborne and satellite observation.

Support environmental resources management

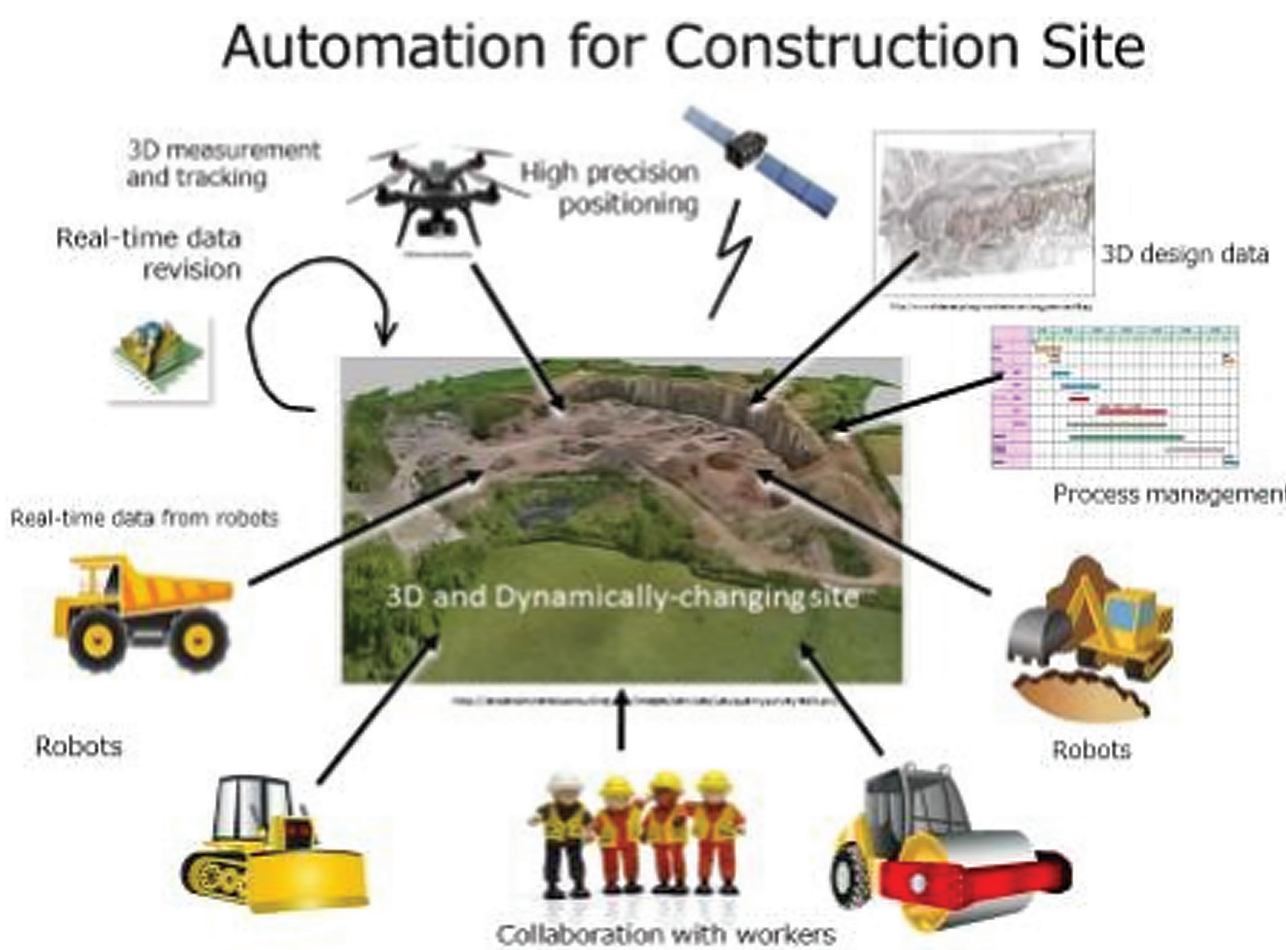
Natural or environmental resource management is an area where digital technologies could make significant contributions because the lack of information on the status of and changes in resources has created difficulties in decision-making and evaluation of actions taken. In addition, through the improvement of efficiency in social systems like transportation/logistics, achieved with the help of SGT, GHG emissions and impacts on the environment can be reduced.



SAR = synthetic aperture radar.

(Source: ERIA, 2018)

Figure 5: Forest monitoring with integrated digital technologies



3D = three dimensional, SGT = space and geospatial technology.

(Source: ERIA, 2018)

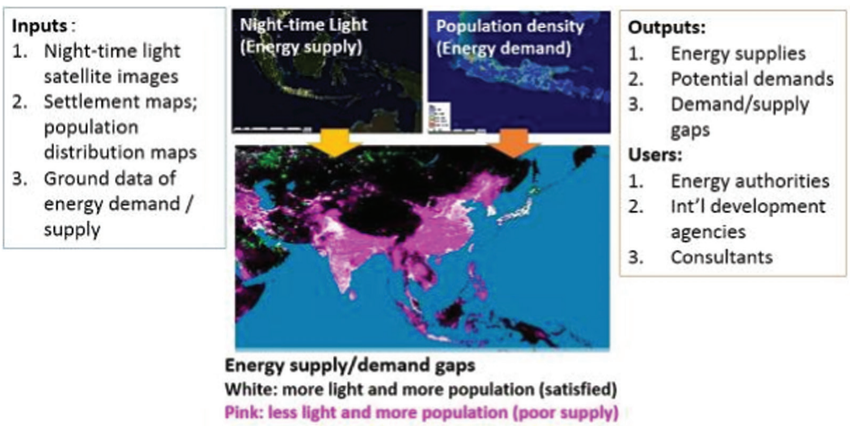
Figure 6: Automation in construction industries with digital technologies

- Carbon dioxide (CO_2) emission reduction by optimizing transport operations (taxi, commercial vehicles, and shipping vehicles) based on vehicle mobility data. This supports fund raising by environment finance schemes such as bilateral carbon offsets.
- Effective conservation of ecosystem services by continuous monitoring of the ecological status of forests, oceans, and marines.
- Social bonds can be applied to improve and sustain the services based on the value evaluation of ecosystem services.
- Effective conservation and management of specific areas for species conservation and gene banks.

Infrastructure needs for integrating the technologies for improved resilience

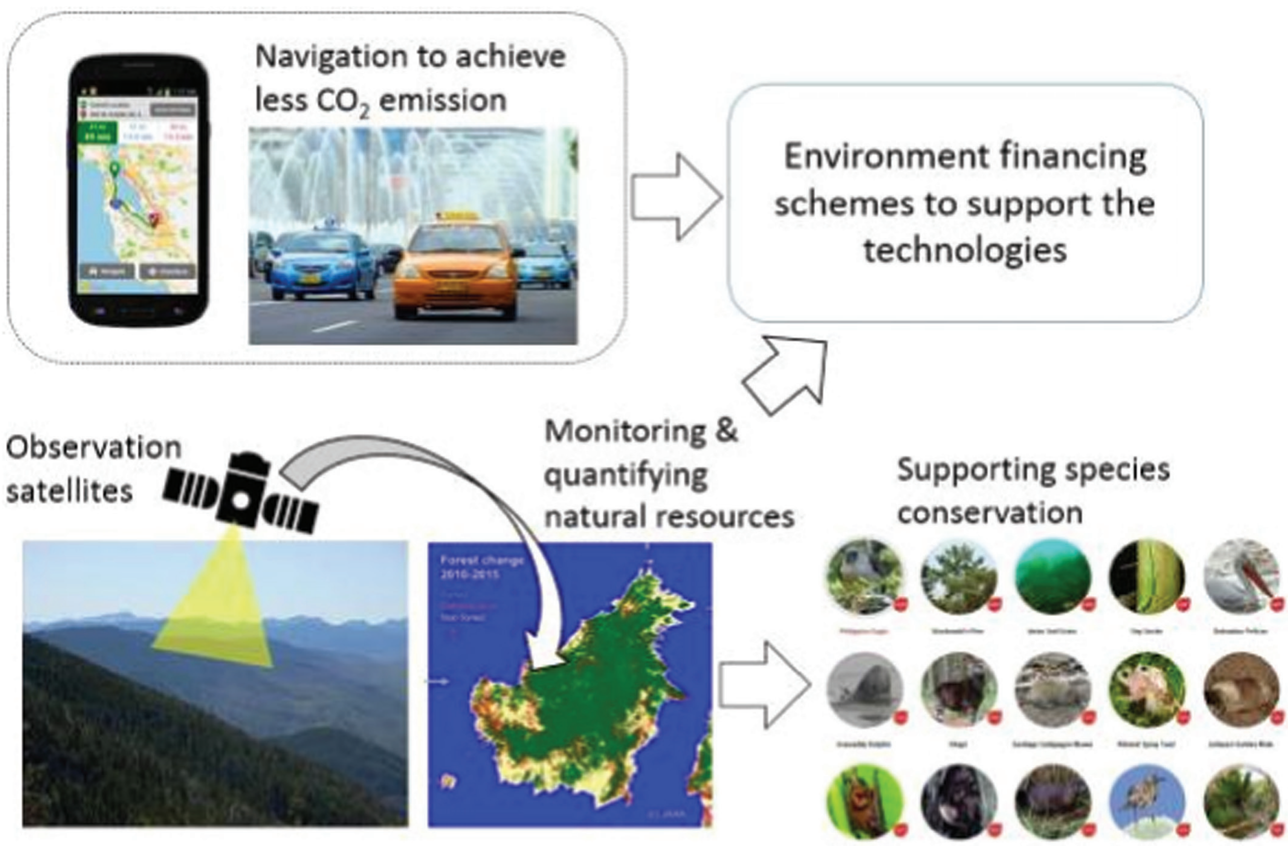
To benefit from the full potential of integrated digital technologies, Asia-Pacific countries will need to adopt coordinated policies aimed at establishing both a strong infrastructure supporting the use of digital technologies and a legal framework to organize digital data utilization.

1. Physical infrastructure:
   - Space systems: observation, positioning, and communication; and



(Source: ERIA, 2018)

Figure 7: Estimating energy needs through night satellite observation



CO_2 = carbon dioxide, SGT = space and geospatial technology.

(Source: ERIA, 2018)

Figure 8: Digital and space technologies for environmental resources management

- Ground-based systems: base station networks, satellite communication points, and ground data networks.

2. Data policies and associated public/industrial policies:
   - Sustainable value creation from data by respecting the rights and concerns of data producers and associated stakeholders.
   - Separation of data holdings/ownership and advanced usage by value creators/producers; and
   - Sharing benefits among data producers and value creators.

Concerning the use of earth observation technologies, different policy approaches could be recommended , depending on the kind of application requested.

In the case of global earth observation, the cost of establishing a large constellation of expensive satellites would be unbearable for developing countries, even if they are united behind this goal. Therefore, it would be beneficial for countries to join global earth observation open data clubs such as the *Group on Earth Observations*. In the case of local observation, countries develop indigenous capabilities through the establishment of regional policies, balancing between competition and collaboration.

A strong focus has been made on the importance of the establishment of an Asia-Pacific constellation. Facing the same challenges on a relatively similar environment and having digital technology as a solution, transcending national boundaries for climate resilience. It would be highly inefficient for member countries to develop in parallel similar technologies without collaborating. Beyond regional utilization, the data produced by satellites could then be shared in a previously mentioned global earth observation open data club.

Conclusion

The rise of digital, information and communication and space technologies has had a deep impact on all layers of society. By combining a highly technological space infrastructure (earth observation, positioning, and communication) with new technologies for data utilization (Artificial Intelligence, IoT, etc.), the contribution of integrated technologies to the climate resilience economy is already visible but should be further promoted.

More specifically, digital technologies could participate in the realization of the Resilient supply chains—a vision of increased climate risk adaptation. It is therefore primordial for industries and policy makers to create a regional cooperation policy framework policy with a focus on four areas of action. First, separating data holdings/ownership and advanced data usage, and integration by value creators, as well as respecting the rights and concerns of data producers/stakeholders. In other words, ensuring a smoother flow of data and a clearer responsibility for data usage. Second, sharing the benefits of value creation from data among data producers and value creators. Third, monitoring and assessing the risks and benefits of data usage and data market competition/concentration in a coherent manner and the fourth, accelerating human resource development of value creation.

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