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Applications of Satellite Remote Sensing in the Environment

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***Abstract*—Since its inception, satellite remote sensing has enabled observations of environmental changes at inaccessible locations in meteorology, disaster control, oceanography, agriculture, glaciology, geology etc. Using the information gathered from satellite remote sensing, changes in the physical environment can be measured and the information are utilized to predict future patterns and achieve better environmental outcomes in different areas. This paper serves to highlight some of the areas in which satellite remote sensing has been applied. In meteorology, Earth's solar radiation intensity, geothermal energy and wind velocity are measured by satellite remote sensing. Satellite imageries are also used for forecasting natural disasters such as floods and earthquakes and estimating damages, including catastrophic events such as the Fukushima Daiichi nuclear disaster. In agriculture, it is used to monitor crop growth and identify potential threats. It has allowed global mapping of change in oceanography such as surface area topography, phytoplankton content, currents and winds, playing an important role in establishing habitat linkage between oceanographic processes and fishery resources. It is also commonly utilized in glaciology, where it allows monitoring and mapping of temporal dynamics of glaciers, and in geology, where it aids the study of mineral composition in the ground. Due to its speed and efficiency in information-gathering, the applications of satellite remote sensing are continually increasing and becoming a vital part in environmental resource management process.**

***Index Terms*— agriculture, disaster control, environmental outcomes, geology, glaciology, meteorology, oceanography, satellite remote sensing**

I. INTRODUCTION

With the global population increasing exponentially, more and more resources are needed to support this growth (Worldometers, 2014). Hence, environmental resources such as forests and oceans are increasingly affected. In order to monitor the usage of these precious resources, various technologies have been implemented.

One of these technologies is satellite remote sensing. Satellite remote sensing is a system of obtaining and analyzing information from a distance through the use of satellites. Its application has become increasingly prevalent in the study of environmental issues. Although other aerial platforms such as airplanes can be used in remote sensing, satellites are more favorable. With their range of sensors on board, satellites are able to provide detailed, regular and almost immediate data with wide coverage worldwide (Liew, 2001).

An example of satellite remote sensing applications is the monitoring of forest fires in disaster control, where hotspots can be monitored by satellite sensors. Also, in oceanography, satellite remote sensors are used to observe the phytoplankton content in the ocean. With the information gathered, environmentalists will be aware if the ecosystem in a particular area is doing well. Besides disaster control and oceanography, other significant applications of satellite remote sensing are in fields such as meteorology, agriculture, glaciology, and geology (Japanese Association of Remote Sensing, 2013).

As resources are in high demand to support the ever increasing global population, studies in the areas mentioned are imperative to ensure that there is no over-exploitation. With the use of satellite remote sensing, environmentalists can obtain valuable information and offer better practices for the benefit of the environment and the human race.

This paper will discuss the different applications of satellite remote sensing and showcase examples of which this technology has been used to achieve better environmental outcomes. Areas of study include meteorology, disaster control, oceanography, agriculture, glaciology and geology.

II. APPLICATIONS FOR METEOROLOGY

Satellite Remote Sensing provides valuable information that supports the introduction of renewable energy to the world, as high quality resource assessments serve as a fundamental guide to successful deployment of these valuable sources (Stiftelsen Det Norske Veritas, 2013). Over the years, both private institutions and the government has utilized collected data of the Earth's solar radiation intensity, geothermal energy and wind velocity to determine if the use of these clean resources is indeed feasible to supply their national energy consumption rate at a sustainable economic level (U.S Department of Energy, 2014). With the aid of remote sensing, uncertainty and risk involved are generally reduced, in turn boosting the likelihood of success in clean

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energy projects and encouraging investors to participate. In the long run, the world would reduce its dependency on depleting fossil fuels and lessen its negative impacts on the environment (Sen, 2004).

A. Case Study: Solar Energy Plants, California

Remote sensing has played an important role in the use of solar energy in many countries including Europe, Africa, as well as the United States. Resource assessment for solar power has become relatively easy and effective through the use of Optical and Infrared Remote Sensing. By interpreting the different color tones and brightness on optical images captured by satellites, researchers are able to specify ground spots with the highest concentration of solar radiation (Appendix A1). In addition, the wide geographic coverage by the satellite surveillance camera provides assessors with more options as to where the project site can best be located, while considering the environmental impacts and financial returns. One example would be the ongoing project, BrightSource Limitless's solar thermal system in California's Mojave Desert, Ivanpah, the biggest scale of a solar power plant ever built, supplies energy to more than 140,000 homes in California during peak hours of the day and reduces carbon dioxide emission over 400,000 tons per year (BrightSource Limitless, 2010). Targeting at the vast desert, the mission was made possible using sensing technology to locate the ideal site with maximal solar radiation for the substantial provision of competitive and reliable solar power to the state.

B. Case Study: Geothermal Development, Indonesia

A key role in the exploration phase of geothermal resource development, remote sensing aids in seeking these hidden gems in the form of underground water reservoirs that have been heated because of their proximity to magma underneath the earth's surface. Color tones from thermal infrared satellite images depicts range of land surface temperature and allows easier discovery of areas with high concentration of geothermal resources, as compared to tedious physical land surveillance of surface manifestation such as hot springs, ground ward, fumaroles, hot mud and others (Appendix A2). From 1997 – 2002, a project was led by Japan's New Energy and Industrial Technology Development Organization (NEDO) to explore geothermal resources in remote islands of Indonesia, with the purpose of increasing the supply of clean energy, which would fulfill the growing energy consumption in Asia. The project was smooth-sailing, through the use of remote sensing in areas that lack sufficient geo-scientific data and accessibility. For instance, night-time infrared imagery enabled the team to accurately extract prospective geothermal areas with less effort (Muraoka, 2003). In short, sensing technology proved to be the most economical method for the project, under the harsh conditions of inaccessible remote islands, in view of the need for rapid exploration.

C. Case Study: Wind Energy Plants, Denmark

Remote sensing is gaining popularity in the wind energy industry, as developers and investors are increasingly confident in its use, to better measure wind characteristics such as in-flow angle and turbulence. Besides that, the technology is capable of characterizing spatial wind field, calculating wind speed and spatial power density distribution over a huge region of interest with high accuracy (Appendix A3). High quality wind speed measurement supported by remote sensing devices such as Lidar is essential for projecting energy production level of most, if not all wind farm projects today. Denmark, well-known for her strong expertise in offshore wind farming, uses satellite radar to perform wind mapping, to support the construction of its current and future wind powerhouses. The Danish government plans to generate a total of 4,000 MW of offshore wind power by 2030. In addition, a Danish study has confirmed the reliability of remote sensing technology in this field, where they achieved more promising results than ground-based measurements of wind speed (Mikkelsen, 2011).

III. APPLICATIONS IN DISASTER CONTROL

Satellite Remote Sensing is applied in the management of natural disasters such as landslides, volcanic eruptions, and determining of hazardous areas to be evacuated if necessary. Besides that, satellite imageries are valuable data in estimating the damages of disastrous events, and supporting rescue missions thereafter (Lewis, 2009). Satellites used in disaster control remote sensing typically have different types of sensors on board with each of them having a specific purpose, for instance, infrared sensors help in flood mapping and thermal sensors pick out hotspots together with volcanic activities. In South Africa, the Council for Scientific and Industrial Research (CSIR) makes use of a mobile application called Advanced Fire Information System (AFIS). It provides farmers and disaster personnel with near real-time fire information by using thermal sensors onboard Earth observation satellites (Frost, 2013).

A. Floods

Government agencies can mitigate losses from natural disasters, through solutions derived from remote sensing technology. In the case of climatological and hydrological hazards such as droughts and floods, remote sensing serves an important role in risk modeling and vulnerability analysis for better management of land use and water resources. Besides that, the technology assists environmentalists in forecasting weather conditions, rainfall mapping, and provides early warning to allow affected regions to prepare for the onset of these natural hazards (Sanyal & Lu, 2004). For example, the Global Flood Detection System (GFDS) monitors floods worldwide using microwave sensing to detect any anomalies on the surface water and instantly reflect the situation by sending detailed recordings to relevant parties automatically (Global Disaster Alert and Coordination System, 2014).

B. Earthquakes

Through hazard mapping, remote sensing can identify vulnerable infrastructures, and recommend intensified metal frameworks to strengthen buildings near earthquake-prone areas to minimize damage in these geophysical events (Revathi, Brahmanandam, & Vishnu, 2011). Furthermore, satellite imagery assists in damage assessment and coordinating search and rescue tasks during a catastrophe. For example, the use of Interferometric Synthetic Aperture Radar (InSAR), a microwave imaging system that combines sequential radar images to measure surface movement, has been used to assess the damage, ground deformation and forecasting of earthquakes (European Space Agency, 2014).

C. Case Study: 2011 Tohoku Earthquake, Japan

The 2011 Tohoku earthquake, also known as the Great East Japan Earthquake, with a magnitude of 9.0 was the most powerful known earthquake that ever hit Japan, triggering tsunami waves up to 40 meters high, claiming over 15,000 lives and set off nuclear meltdowns at Fukushima. PASCO Corporation, a satellite imagery establishment based in Tokyo, supported local authorities in managing the disaster by providing crucial geospatial imageries within the first 24 hours, and subsequent observations every 24 hours. Pre-disaster and post-disaster images were compared to establish affected regions and flooded areas, and the level of inundation was monitored through synthetic aperture radar satellite (TerraSAR-X) (PASCO, 2012). In Appendix B1, the pink, orange and red area depicts flooded area on March 13th (two days after the quake), March 24th and April 4th respectively.

IV. APPLICATIONS IN AGRICULTURE

As globalization has decreased primary production industries over the recent years, it is increasingly vital to monitor crop growth and optimize productivity in the agricultural industry today. To acquire the resource data efficiently for current and future developments, satellite remote sensing has been introduced to assist farmers in crop assessment. With this technology, farmers are able to manage and scrutinize closely on the usage of fertilizers on crops, temperature and humidity in the soil and also factors concerning insect infestations and crops diseases (Satellite Imaging Corporation, 2013).

Reflected solar radiations from the ground material have their own unique spectral reflectance signature. The multispectral imaging system of remote sensing technology arranges this data into color images for interpretation. When the same material reflects an irregular wavelength as compared to the typical reflectance spectra as shown in Appendix C1, it indicates that the targeted area might be contaminated and an investigation is necessary. A list of remote sensing systems is used and can be categorized by the number of spectral bands used. Some of the renowned sensors are Multispectral and Panchromatic sensors and each caters for different needs (Satellite Imaging Corporation, 2013). The wavelengths received can be used to calculate NDVI (Normalized Difference Vegetation Index), which is essential to identify problems like moisture in the soil and plants, plant diseases and pest infestation. For instant, the left image in Appendix C2 shows high yield in the blue area while the right image shows high acidity in the soil. By analyzing the colors in the images, farmers can understand various problems like water deficit, crop stress and low soil quality. Moreover, farmers can apprehend the health of the vegetation by their reaction towards sunlight during photosynthesis. When crops are diseased, photosynthesis will decline and light will be less absorbed (Woodrow, 2011). Furthermore, these calculations measure the optimal requirements of the crops and prevent over or under application of fertilizers and nitrogen. Satellite remote sensing not only allows for early yield prediction, but also assists in the impact on environmental stewardship due to nitrogen management. These applications provide farmers with timely and valuable information that can reduce costs and improve the numbers in crop yield.

A. Food Crisis

After the world food price crisis in 2007-2008, the importance of remote sensing in agriculture was recognized. Several countries experienced major price hikes that led to food insecurity worldwide. Researchers identified that climate related incidents played a part in causing dramatic decrease in crop production (Oxfam Organization, 2014). Various policies like the introduction of new technologies to developing countries were implemented to solve the crisis (U.S. Department of State, 2011). To prevent food insecurity, the U.S. Geological Survey (USGS) collaborated with the Famine Early Warning Systems Network (FEWS NET), to effectively monitor the agricultural industry and identify any potential threats internationally by using satellite remote sensing to collect data.

B. Case Study: Afghanistan

To validate the credibility of using satellite remote sensing to provide food security information accurately, one of the researches was conducted in Afghanistan using NDVI data (Appendix C3). A comparison was made between the production of winter wheat during year 2000 and 2008. After using the Moderate Resolution Imaging Spectroradiometer (MODIS) with 16-day composite NDVI time series and wheat yield statistic to compare the difference between year 2000 and 2008, the results showed that the maximum NDVI was the lowest in year 2008 due to poor irrigated and drought conditions. This result was proven to be accurate as a usual climate change had created drought in most areas in Afghanistan during year 2007 to 2008. This clearly showed the effectiveness of using remotely sensed satellite observations as a guide to make future strategic decisions and prevent any undesirable outcomes (Budde, Rowland, & Funk, 2010).

V. APPLICATIONS IN OCEANOGRAPHY

With the hydrosphere constituting more than two thirds of the Earth’s surface, it is impractical and costly for oceanographers to dispatch research vessels for gathering the comprehensive and reflective aquatic data. As an activity in one area of the world’s ocean may be dependent on another area, oceanographers are required to study the oceans as a total system. Hence, satellite remote sensing comes in play (Museum of Science, 1998). Satellite remote sensing provides total ocean surveillance and data on a global scale as it enables global mapping of changes in areas such as surface area topography, phytoplankton content, currents, winds and many more. For example, in the case of phytoplankton content, satellite images can derive the areas in which these primary producers are thriving and draw conclusions on the health of the ecosystem. The information gathered could then help environmentalists in the location of bivalve molluscs such as clams, oysters and mussels. An area with a high yield of phytoplankton will be an ideal site for these filter feeders as nutrients are already present in that particular region. All the abundant available energy will be utilized and additional costs could be saved. Furthermore, the introduction of bivalve molluscs could promote a much healthier ecosystem.

A. Case Study: Northern Arabian Sea

A study based in the Northern Arabian Sea observed oceanographic processes such as upwelling events and formation of eddies, rings and fronts, so as to identify ecological associations for further fisher resources exploration (Solanki, 2008). Observations during the project were carried out using the National Oceanic and Atmospheric Administration Advanced Very High Resolution (NOAA AVHRR) and the Indian Remote Sensing Satellite-P4-Ocean Colour Monitor (IRS-OCM). In the report, researchers complimented the potential of satellite remote sensing in establishing habitat linkage between oceanographic processes and fishery resources. Remote sensing is particularly effective in monitoring both cyclonic and anti-cyclonic eddies, for their formation, persistence and impact on biological production. Appendix D1 & D2 represents the observations of eddies showing different chlorophyll concentration level in cyclonic and anti-cyclonic regions. Chlorophyll allows plant cells to convert sunlight into energy, thus enabling its growth. As eddies are mobile, there is always diffusion of nutrients level among these areas which in turn enhances ecological productivity and sustainability. Richer ecosystem only exists in cyclonic eddies that are abundant in nutrients that promote the development of plankton. On the other hand, anti-cyclonic eddies are devoid of nutrients and considered as biological deserts with minimal life forms. By taking advantage of knowing these eddies' attributes and whereabouts, fishermen can then fish sustainably, and oceanographers are better aware of the marine ecosystem's overall development.

VI. APPLICATIONS IN GLACIOLOGY

Since the emergence of satellite remote sensing, data gathering for glaciology has become easier for researchers to conduct effective monitoring and mapping of temporal dynamics of glaciers. In recent years, the technology has become dominant and plays a major role in measuring changes of glacier and ice-sheet mass balance, based on remotely sensed measurements of glacier flow, surface elevation and the gravity field (Luthcke, Pritchard, & Fleming, 2010). One of the assessment methods is to measure volume changes with repeated satellite altimetry and converting this to mass, using estimates of the density of snow or ice lost or gained by Ice, Cloud and land Elevation Satellite (ICESat). The mass balance of glacier and ice-sheet is also assessed by measurement of mass change directly with repeated gravimetry by Gravity Recovery and Climate Experiment (GRACE) Satellite Sensor. Another method is to calculate flux imbalance using measurements of glacier flow and knowledge of glacier thickness and surface balance (Pritchard, 2010). Through the three approaches, other than the mass balance being calculated, it also allows for a deeper understanding of the causes and mechanisms pertaining to the diminishing ice mass and glacial sea-level contribution.

A. Case Study: Swiss Alps

A test was carried out in the densely populated Swiss Alps, to develop and evaluate remote sensing based methods that allow a systematic detection of glacier lakes and their hazard potential (Huggel, 2001). The focus of the project was specifically on the applicability of preventive measures in inaccessible regions and on integrative risk assessment over a wide area, with both favoring the use of remote sensing technology. The initial stage involved the use of space borne remote sensing in discovering semi-frozen pools with high temporal variability over the mountainous region, followed by subsequent stages of GIS modeling and risk analysis (Appendix E1 & 2). Besides detection, the technology is effective in monitoring the ever-changing conditions of the lakes and their evolution into hazardous articles, as compared to wearing field investigations. In the process, multispectral satellite imagery was specifically used to determine if a lake is dammed by ice, moraine or bedrock. Another function involves the ability to check for potential trigger mechanisms, such as displacement waves from snow avalanches, rock fall or calving glaciers that will provoke a lake outburst (Grabs, 1993). More importantly, sensing tools recognized narrow passages such as gorges and endangered settlements in the flood path. With this knowledge, local authorities are able to pre-warn residents and carry out necessary procedures such as relocating settlements, building drainage pathways or dams to minimize impacts from any lake outburst. Thus, remote sensing monitoring has become more crucial since global warming shifted glacial hazard zones into a disturbing level with no accounted historical analogues.

VII. APPLICATIONS IN GEOLOGY

Responsible for the new era in mapping lithology, remote sensing opens up unlimited possibilities of ways in surveying the comprehensive topographic surface of the Earth. Shifting away from the traditional method of conventional ground surveys based on field observations, the mapping of lithology and alteration zones in inaccessible mountain and forest terrains has been made accurate and convenient with the introduction of remote sensing (ASD Inc., 2013). The synoptic view by the technology is greatly appreciated for providing regional and integrated perspective of inter-relations between various land features, lithological contacts and geological structures in great details (Samih Al Rawashdeh, 2006). Airborne imagery obtained from multi and hyper spectral imaging sensors such as ASTER, Landsat and Hyperion is applied to geological surveys, alteration zones mapping, geomorphology applications and indication of subtle shifts in mineralogical composition (ASD Inc., 2013).

A. Case Study: Al-Ezraq

A lithological and structural study was carried out in El-Azraq for mineral exploration through the use of remote sensing (Samih Al Rawashdeh, 2006). From different topography and roughness of ground, moisture and the chemical and physical characteristics of soil, different tones of radar waves were captured by the LandSat and used to distinguish existing mineral composition levels (Appendix F1). Several different image analysis techniques such as Ratioing and Principal Component (PC) analysis were tested to determine which are most suitable for specific lithology discrimination. In this case, PC analysis proved to be informative for the basalt formation, and Ratioing provides specific geological information with higher contrast between color tones than the conventional color images by LandSat (Appendix F2 & 3). Through this study, it has clearly shown that remote sensing tools are efficient in geological mapping, which then leads to well-informed mineral extracting, and thereby reducing unnecessary uprooting of the Earth's resources.

VIII. CONCLUSION

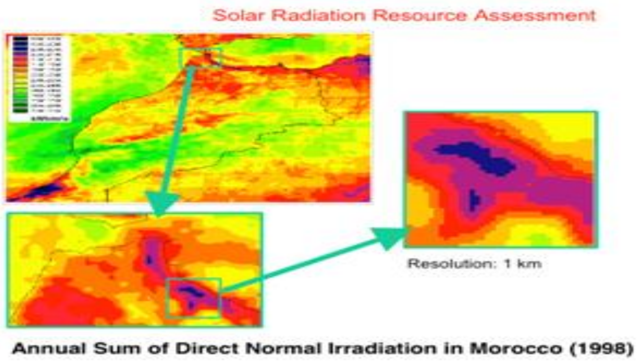
The applications of remote sensing have increased in recent years, considering the advances in technology. The different case studies have shown the importance of remote sensing technology in monitoring environmental hazards, from managing natural disasters to monitoring crops.

As the importance of environmental information increases, the use of remote sensing is likely to grow. Satellite remote sensing provides data concerning those areas deemed inaccessible such as mountainous areas. Since information of a large area can be gathered quickly, time and efforts of human beings can be saved. Without the introduction of satellite remote sensing, research would have been done on site and information might not have been as accurate or reliable. Planes would also then have to be deployed for manual observations, with restrictions of weather conditions for take-off, fuel capacity and altitude limits, amongst other concerns. Satellites, on the other hand, can provide wide-area coverage, and are not limited by inclement weather.

Nevertheless, obtaining quality image data in a short time frame remains a challenge. It is notable that the costs of building and operating remote sensing equipment are high, especially for better resolution images, where a fair amount of money has to be invested. However, its applications are far and wide, and have proved to be useful in many aspects. Through the usage of satellite remote sensing technology, environmentalists are now in a better position than before to ensure that ecosystem are protected and maintained for future generations with considerations of ethical, economic and ecological variables. In conclusion, it is crucial for continual advancement of sensing technology to provide faster and more efficient information-based services in working towards a sustainable environment.

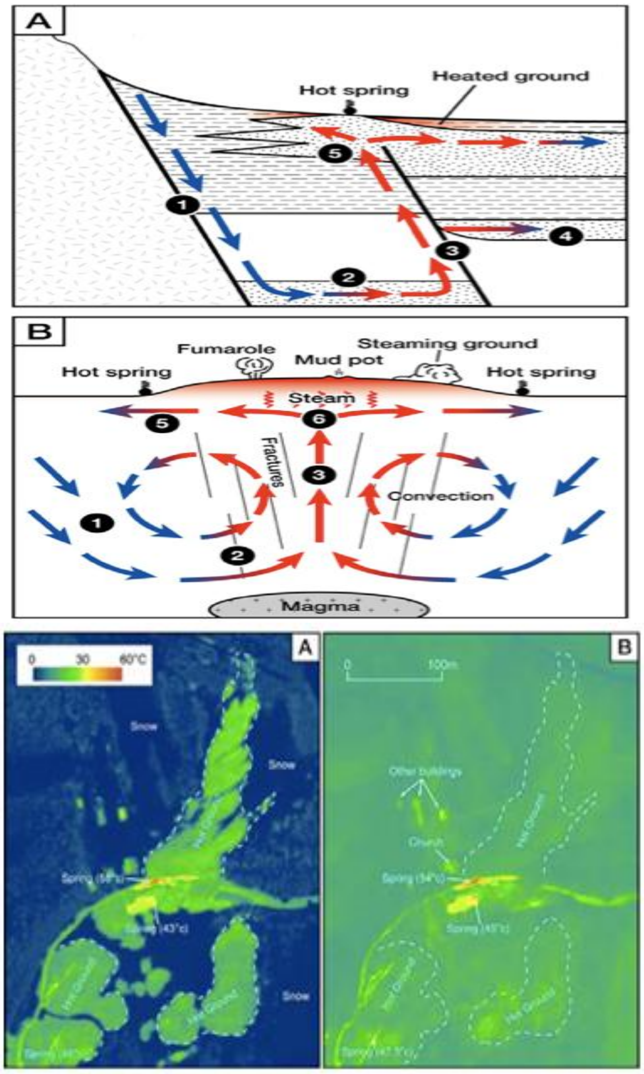
APPENDIX

A. Appendix A1



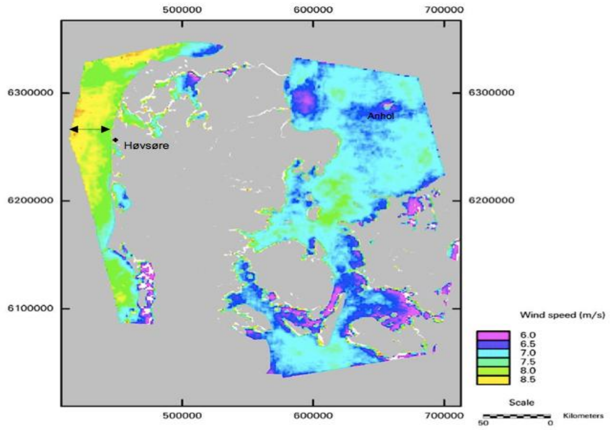
Source: Image of Solar Radiation Resource Assessment (Trieb, 2001)

B. Appendix A2

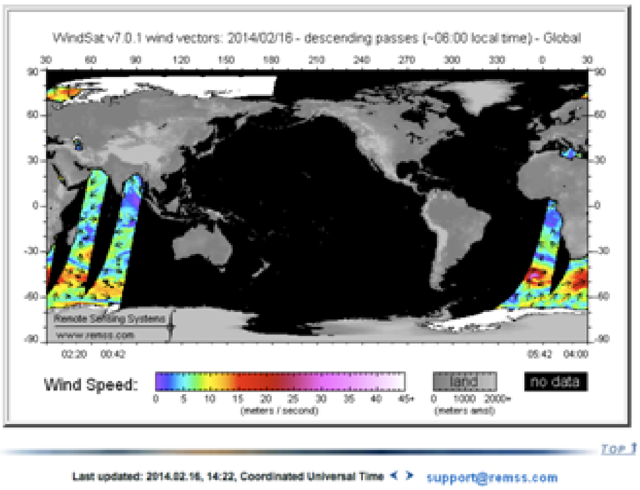


Source: Detection of Hot Springs (Prakash, 2011)

C. Appendix A3



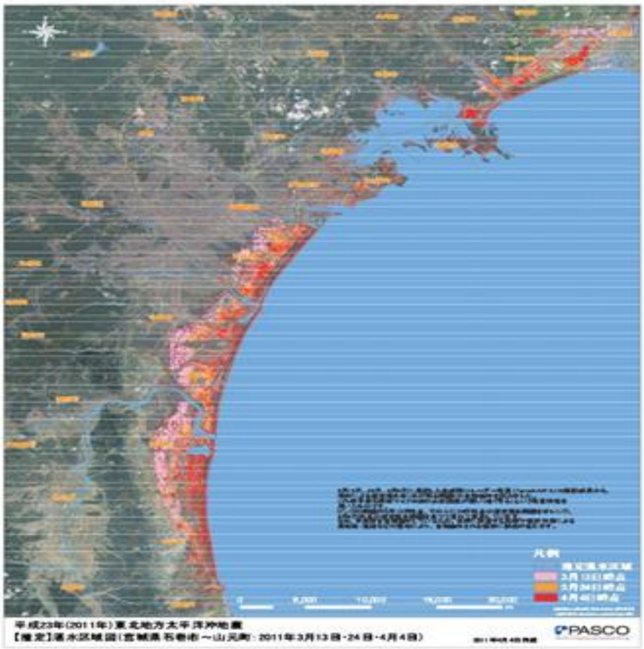
Source: Wind velocity mapping (C.B. Hasager, 2006)



Last updated: 2014.02.16, 14:22, Coordinated Universal Time support@remss.com

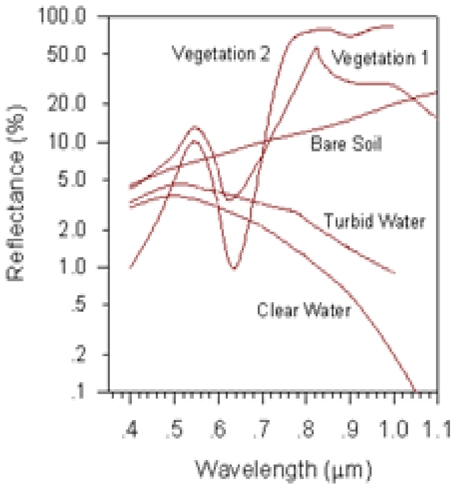
Source: Wind vector data (Remote Sensing Systems (RSS), 2014)

D. Appendix B1



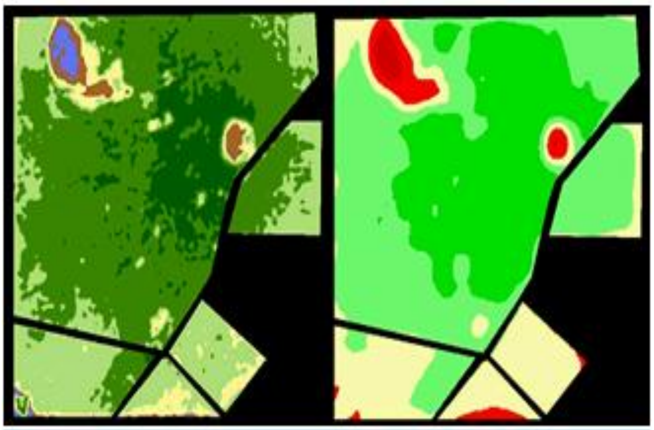
Source: Inundated Flood Areas after Earthquake (PASCO, 2012)

E. Appendix C1



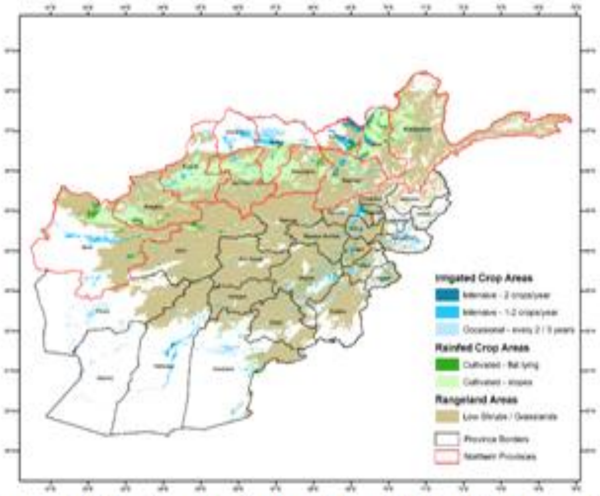
Source: C1 shows the typical reflectance spectra of five materials: clear water, turbid water, bare soil and two types of vegetation (Woodrow, 2011)

F. Appendix C2

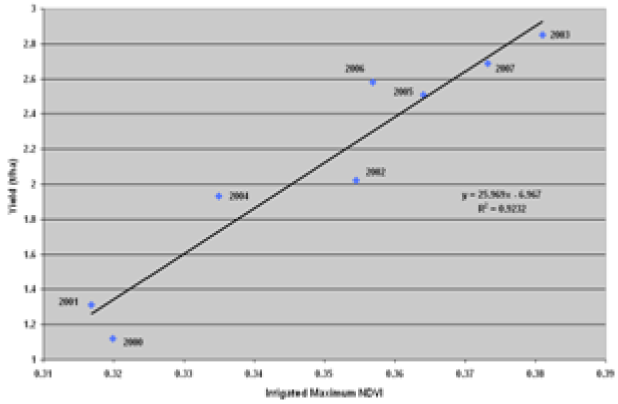


Source: Map of Soil Acidity (Woodrow, 2011)

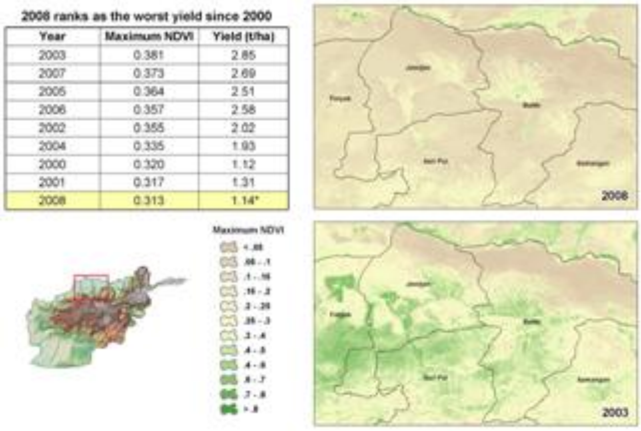
G. Appendix C3



Source: Afghanistan Agricultural Lands Map (Budde et al., 2010)



Source: Correlation of maximum NDVI and wheat yield (Budde et al., 2010)



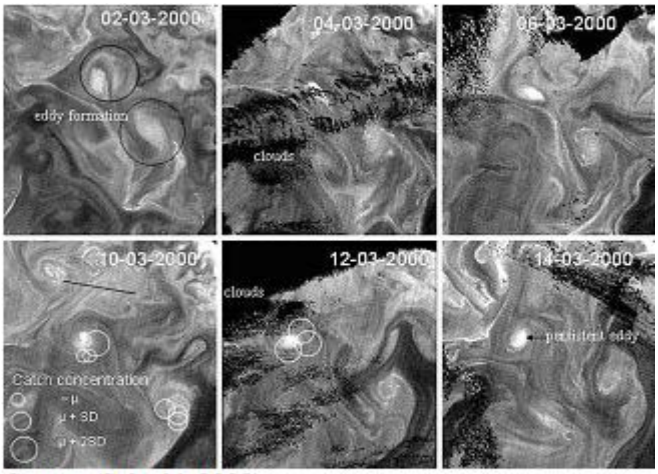
2008 ranks as the worst yield since 2000

Year	Maximum NDVI	Yield (t/ha)
2003	0.381	2.85
2007	0.373	2.69
2005	0.364	2.51
2006	0.357	2.58
2002	0.355	2.02
2004	0.335	1.93
2000	0.320	1.12
2001	0.317	1.31
2008	0.313	1.14*

Source: Maximum NDVI ranking and comparison to a productive year. Estimated yield (*) (Budde et al., 2010)

H.Appendix D1

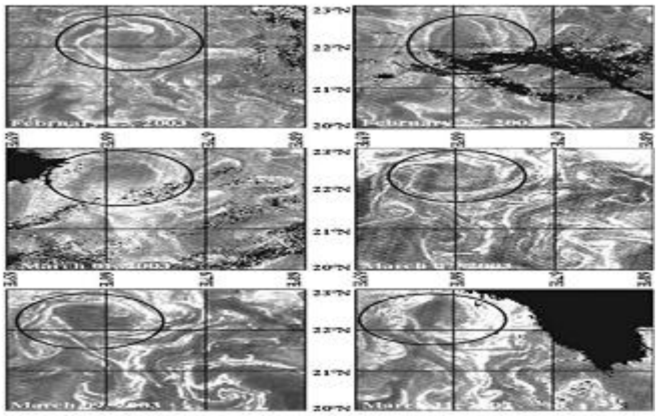
Sequential images of OCM-derived chlorophyll concentration show eddy formation, their persistence, and their relevance to fish catch. White circles indicate classified fish-based mean (l) and standard deviation (SD). The darker to lighter tone indicates the lower to higher chlorophyll concentration.



Source: (Solanki, 2008)

I. Appendix D2

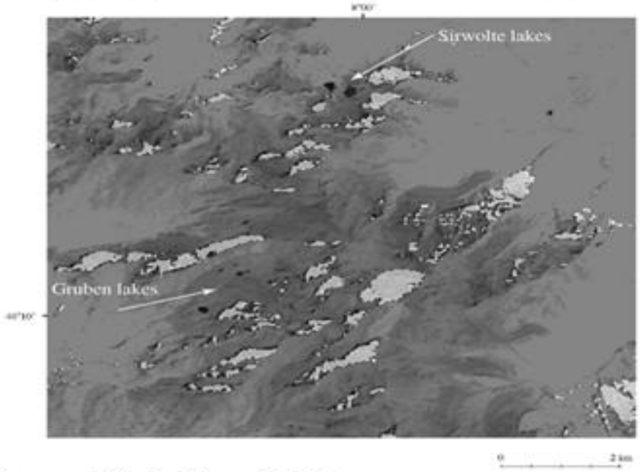
Satellite observations of anti-cyclonic eddy using OCM data during February – March 2013. Darker to lighter tone indicates the lower to higher chlorophyll concentration. Anti-cyclonic eddy with poor chlorophyll concentration shown in the circle.



Source: (Solanki, 2008)

J. Appendix E1

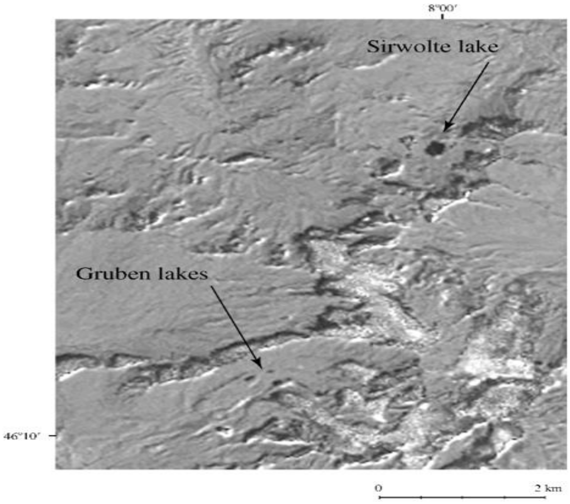
Fig. 8. NDWI for lake detection image based on a 1990 Landsat-TM image overlaid by a shadow map (pixels in light grey). Areas indicated by arrows are discussed in the text.



Source: (Christian Huggel, 2002)

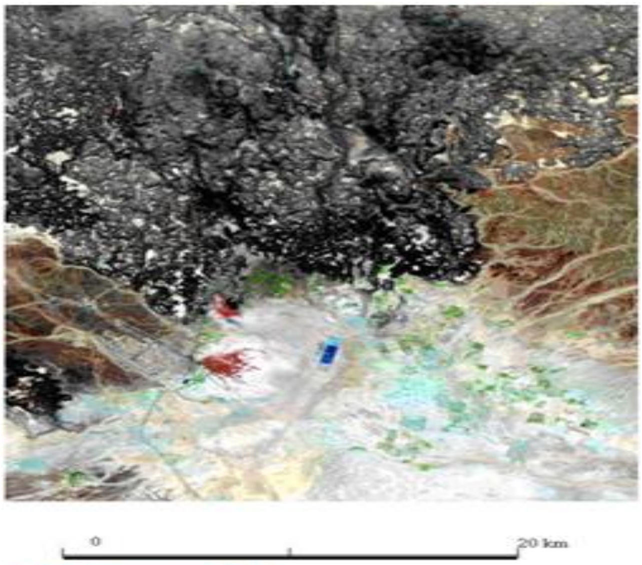
K.Appendix E2

Change detection image generated by channel ratio of two Landsat-TM images (1990 and 1998, using TM5). Areas which were subject to changes between 1990 and 1998 appear in black or white. Areas of interest are indicated by arrows.



Source: (Christian Huggel, 2002)

L. Appendix F1: LandSat Image



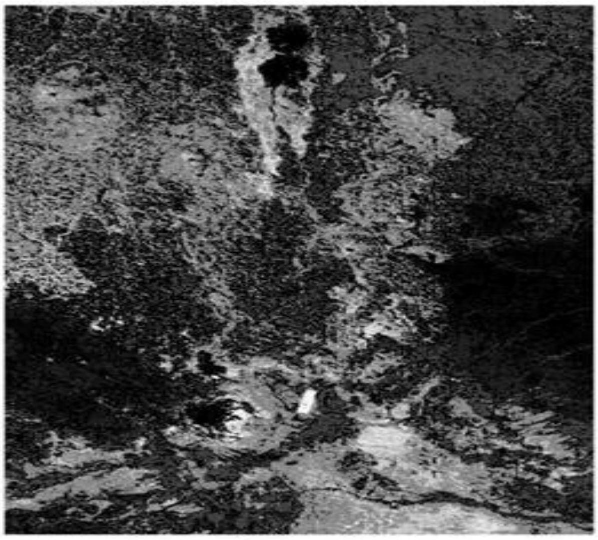
Agrandir Original (png, 464k)

Figure 3 : Enhanced Landsat ETM+ (bands 7, 4 and 2) showing the main geological formations in the study aera

Source: (Samih Al Rawashdeh, 2006)

M. Appendix F2

The Principal Component (PC) Analysis process allowed the extraction of new information. It shows the directions of grey levels distribution in feature space. In general, PC analysis is a statistical technique widely used in RS to choose the suitable bands and to show spectral differences which helps to display clearly the correlation of the spectral values between the different channels. Due to the large number of spectral bands, much information was acquired from LandSat ETM+ images, especially in the infrared region of the spectrum. As result, these data were very useful for lithology, soil and terrain pattern differentiation. After Principal Component transformation, using linear and nonlinear adaptive stretches, visual inspection of the PC color composites indicates that the composite containing the first three PCs were the most informative mainly for the basalt formation.



Agrandir Original (png, 291k)

Figure 4 : Resulted image of principle component transformation, constaining the first three PCs, showing the different

Source: (Samih Al Rawashdeh, 2006)

N. Appendix F3

For Lithological and alteration mapping, ratio images were used in this study. They were prepared by dividing the digital number (DN) in one band by the corresponding DN in another band for each pixel, stretching the result value and plotting the new values as an image. This method is used by (Weissbrod et al. 1985; Cappiccioni et al. 2003; Edgardo 1992) to extract spectral information from multi-spectral imagery. Color Composite of ratio images 3/1, 5/7 and 3/5 (RGB) express more geological information and provide higher contrast between units than the conventional color images

Agrandir Original (png, 252k)

Figure 5 : Color composite of ratio images 3/1, 5/7 ans 3/5 prepan Landsat ETM+ expressing the main geological formations.

Source: (Samih Al Rawashdeh, 2006)

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