UNEP Global Environmental Alert Service (GEAS)
Taking the pulse of the planet: connecting science with policy
Website: www.unep.org/geas E-mail: geas@unep.org

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Thematic focus: Climate change, Ecosystem management, Environmental governance

From Hotspots to Hopespots: Connecting local changes to global audiences

As changes to ecosystems and the environment continue to occur in response to growing population pressure and natural processes, ways to measure and observe these changes on a regular basis will become increasingly important. Satellite imagery offers an important way to provide evidence of such changes and connect local changes to wider audiences.

Why is this issue important?

A significant area of Earth's surface that is susceptible to slow-onset or rapid environmental change is referred to here as a â€˜hotspot' and is explained through the use of two or more satellite images showing change over time (a â€˜change pair'). A positive outlook for the future is captured through the concept of a â€˜hopespot' which encompasses areas where actions have led to, or are leading to, positive changes. These images, when accompanied by a short storyline and ground photos, are an important method for communicating environmental changes and their impacts to the international community and can ultimately function as a unique decision-support tool.

Visually obvious and compelling stories of positive and negative environmental changes and the transition of hotspot to hopespot can be told through satellite imagery. Scientific articles can be complex, offering numbers or graphics that can sometimes be challenging for non-scientists and decision-makers to visualise and comprehend. Satellite imagery can put those numbers into perspective by offering a way to monitor our shrinking resource base and visually document the extent of the many ways that humans and natural processes have had an impact on our planet (UNEP, n.d.a). In addition, changes may not be noticeable on an everyday time scale, but when examined over an extended period of time and the present can be compared with the past, changes, and their impacts, become increasingly evident. A more temporal and accurate method of observing and documenting the changes the environment has undergone, and continues to face, is needed. Satellite data is one type of mechanism that can be used to accomplish this feat (Hansen and Loveland, 2012).

Figure 1: UNEP environmental change hotspots hosted at https://na.unep.net

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The United Nations Environment Programme (UNEP) has identified more than 200 environmental change hotspots in its *Atlas of Our Changing Environment* series, and other publications, and continues to do so through constant monitoring and research. The hotspots illustrate changes over thousands or millions of hectares of land or coastline spanning more than 100 countries and all seven continents (Figure 1). Satellite images and supporting storylines are hosted at https://na.unep.net, www.uneplive.org and as a GoogleEarth layer where the images are free for download. Animations of some of the hotspot change sequences are also available through the website, offering another dynamic way of viewing and understanding environmental change. The hotspots and *Atlas* series have helped to create environmental awareness around the world.

Many methodologies can be employed to identify potential hotspots, including:

- Laboriously examining wall-to-wall satellite imagery from the many image-capturing satellites in orbit
- Performing specific scientific sampling analysis to detect changes, which can be precise, but also time-consuming
- Using knowledge-based analysis

Due to limited resources, the latter approach is used by UNEP to identify environmental change hotspots. The knowledge-based process identifies hotspots through:

- Consultations with visiting scientists and subject matter experts (SMEs)
- Reviews of scientific literature
- Keeping up with current events
- Using institutional knowledge

Many of the UNEP hotspots are focused on Africa due to the amount of research UNEP has conducted on the continent and the many *Atlases* and other publications stemming from the research (Figure 2).

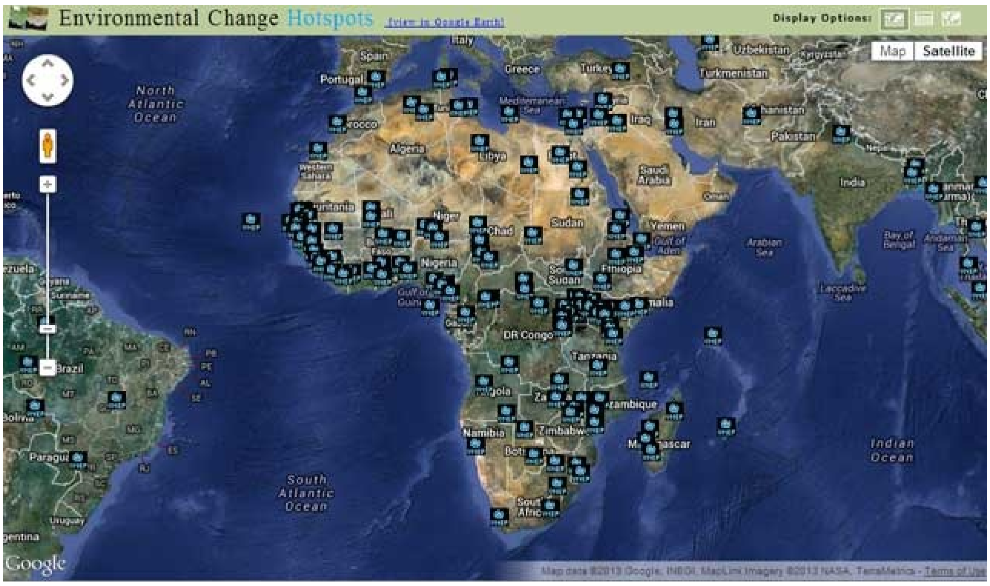

Figure 2: UNEP environmental change hotspots of Africa hosted at https://na.unep.net

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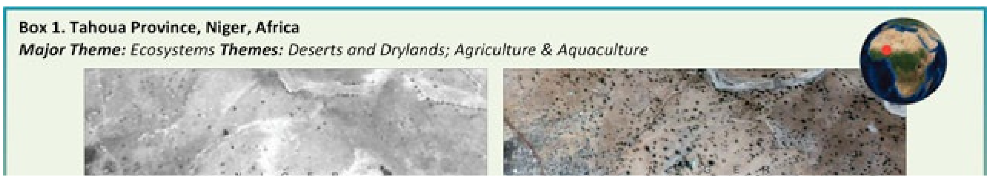

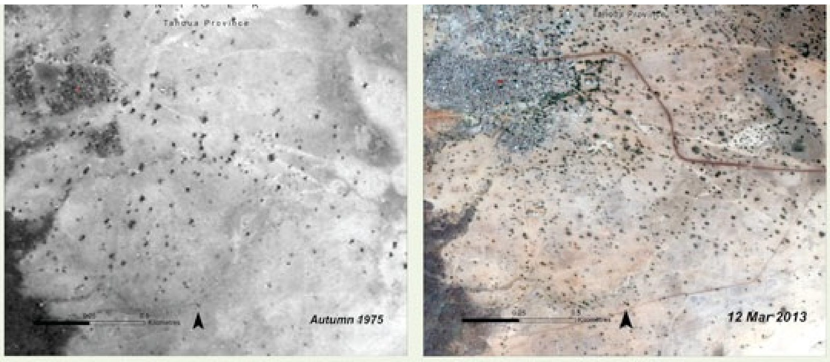

The Tahoua Province is found in a southern area of Niger that is semi-arid and conducive to rain-fed agriculture and pastoralism, but in recent decades, Niger's climate and its demographic problems have forced agriculture onto land that did not receive much rain and historically had been used for livestock. The aerial image from 1975 shows how this change of practice resulted in acute environmental devastation. However, land revitalisation projects over the past few decades, such as tree planting and farmer initiatives to protect the trees, have led to a significant increase in the number of trees across three of Niger's southern provinces. The influx of trees, evident in the 2013 Quickbird image, has helped to reduce drought vulnerability and reliance on rain-fed crops.
Source: Adapted from UNEP, n.d.b; 1975 image: UNEP, n.d.b; 2013 image: DigitalGlobe; visualisation by UNEP/GRID-Sioux Falls

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What are the findings?

The UNEP environmental change hotspots feature a time series of two or more satellites images to demonstrate positive or negative large-scale local environmental changes. Four major themes are used to classify the hotspots: Ecosystems, Resource Extraction, Climate Change and Atmosphere and Disasters and Conflicts. From there, the hotspots are classified into additional minor themes such as Population and Urban Growth, Water and Agriculture and Aquaculture. A breakdown of how many countries and continents are represented by each major theme, and the number of corresponding hotspots, is presented in Table 1. The changes that these satellite images depict include ecosystem restoration (see Box 1), impacts of mining and other resource extraction activities (see Box 2), forest loss and/or gain (see Box 3), changes in glacier mass balance, altered coastlines and shrinking freshwater ecosystems (see Box 4) among others. Selected hotspots also feature a significant environmental event that a location has experienced, such as a volcanic eruption. However, it is important to note that not all types of environmental changes are evident in images. Changes occurring in deep ocean ecosystems or seasonal changes would not be very well represented by satellite image change pairs as the changes might not be very apparent, or the viewer could be convinced that significant changes are occurring, even if they are not.

Theme	# of Hotspots	# of Countries	# of Continents
Climate Change and Atmosphere	10	14	5
Disasters and Conflicts	10	13	3
Ecosystems	156	92	6
Resource Extraction	29	25	6

Table 1: UNEP environmental change hotspots by theme

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Box 2. Three Gorges Dam, China, Asia
Major Theme: *Resource Extraction* ***Themes:*** *Water; Energy and Mineral Extraction*

The Three Gorges Dam on the Chang Jiang (Yangtze) River in China was constructed to supply approximately one-ninth of China's electricity. It is a relatively environmentally clean option compared to coal burning or nuclear power plants. However, the Dam project has had negative environmental and social impacts including the submergence of land along the river above the Dam. The 1987 image shows the nature of the river and surrounding landscape before work on the dam began. In the January 2013 image the Dam is clearly visible, as is the reservoir of impounded river water that has been created behind it.
Source: Adapted from UNEP, n.d.b; Images: Landsat, visualisation by UNEP/GRID-Sioux Falls

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There are many types of Earth-observing, image-capturing satellites in orbit, operated by a number of countries and organisations, including sixteen operated by the United States National Aeronautics and Space Administration's (NASA) in support of its Earth science missions (Figure 3). These satellites have varying capabilities regarding the type of images they can take, as well as image resolution (level of detail visible in the image). Some types of satellites can capture chlorophyll concentrations, sea surface temperature and aerosol content in addition to simply capturing an image. At times, aerial imagery, acquired by cameras on airplanes, can also be used for change pairs or image time series showing environmental change if suitable satellite imagery was not available for the area of interest.

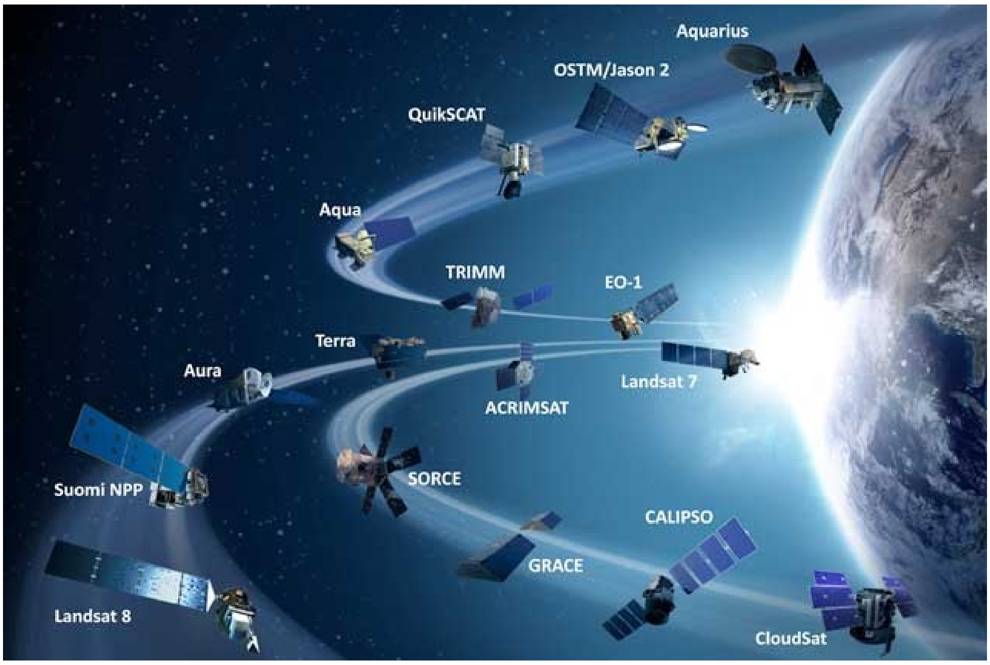

Figure 3: NASA's sixteen Earth-observing satellites currently in orbit. Source: NASA, 2013

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However, the Landsat series of satellites is most often used to create UNEP hotspot images and perform additional scientific analysis. First launched in 1972, the Landsat programme offers more than 40 years of vast spatial coverage â€“ the longest continuous data record of Earth's surface available (NASA, 2012). The Landsat imagery is free to download from the United States Geological Survey Earth Resources Observation and Science (USGS/EROS) center archives (http://earthexplorer.usgs.gov/). The extensive history of Landsat enables all users to witness change of the planet's surface over many decades, thus creating a better understanding of the magnitude of environmental change that an area has experienced and how much the change has influenced the surrounding ecosystems and human populations.

Images captured by the Landsat satellites, including those from imagers on the recently launched Landsat 8, have different bands that can be combined to create an image that allows users to detect different environmental change elements such as fire scars, drought and variations in land use, making it an advantageous observation tool. Landsat imagery is especially suitable for detecting ecosystem fragmentation and degradation and offers a resolution (level of detail) that is ideal for developing comprehensive land cover classification datasets, another way to detect land use change (Giri et al., 2013). Recent uses of Landsat imagery are presented in Figure 4. Due to factors such as lack of temporal availability or presence of cloud cover, it sometimes can be difficult to obtain enough imagery to create a change pair or time series over certain areas of the world using imagery from one type of satellite. Therefore, imagery from other satellites must be used as well.

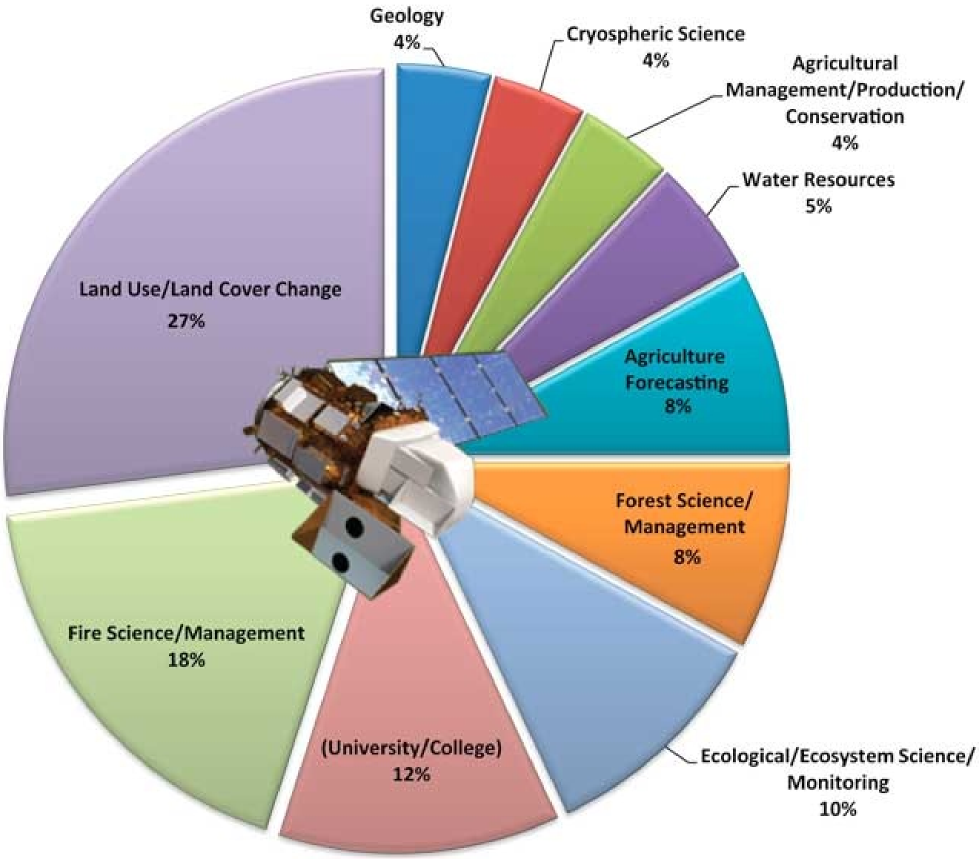

Figure 4: Primary uses of Landsat as recorded by the USGS from October 1, 2012 to April 30, 2013; Source: Adapted from USGS, 2013; visualisation by UNEP/GRID-Sioux Falls

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The environmental change hotspots identified by UNEP have enabled scientists, decision-makers and the general public to visualise changes such as:

- Widespread deforestation throughout South America
- Reduction in glacial coverage in mountainous zones and polar regions, but also glacial advance, as evidenced by the Hubbard Glacier in Alaska, USA
- Impact of diversion of water sources for irrigation in North and East Africa and West Asia
- Significant changes in land appearance, and ensuing impacts, due to introduction of resource extraction activities in places such as North America and Australia
- Efforts of reforestation in the Mabira Forest Reserve in Uganda and in the semi-arid regions of Niger and the general absence of major frontiers of deforestation in Africa

Box 3. Mato Grosso, Brazil, South America

Major Theme: *Ecosystems* ***Themes:*** *Forests; Population and Urban Growth*

Mato Grosso, a Brazilian Amazonian province, lost 13.6 million ha of forest between 1988 and 2012, accounting for about 33 per cent of the total amount of forest loss in the entire 'Legal Amazon' over the same time period. Deforestation was prompted by the construction of major highways through the region and the ensuing development of supporting infrastructure; white areas in the 2012 image indicate where forest has been replaced with agriculture and development. The rate of loss peaked in 2004, and although rates have slightly subsided, deforestation is still ongoing and the destruction may have already inhibited secondary forest growth.

Source: Adapted from UNEP, n.d.b; Images: Landsat, visualisation by UNEP/GRID-Sioux Falls

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Continual monitoring is essential to fully evaluate and gauge the impact of environmental changes, both positive and negative, that the planet faces. To do this, imagery of existing hotspots will continue to be, and should be, updated on a regular and scheduled basis, accompanied by new observations and measurements for existing hotspots and the initiative expanded to identify new hotspots and hopespots.

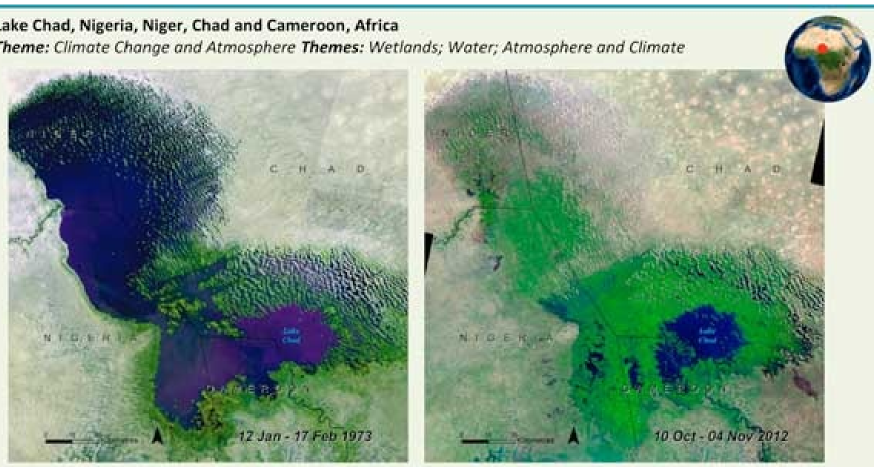
What are the implications for policy?

The identification of hotspots and hopespots, and the images used to illustrate them, can provide insight to the potential long-term consequences that human activities can have on the environment. This insight can help decision-makers to identify and form policies, regulations and corrective measures for future sustainable development. As a decision-support tool, the images, and the measurable changes derived from them, can enable more informed decision-making during the policy formulation process. This is possible through the creation of more accurate datasets, increased exposure of changes and as a way to visualise transboundary changes. In addition, the ease of availability of satellite imagery and its current temporal nature increase its importance in the creation of recent and accurate datasets.

Imagery can also serve as a compliance-monitoring tool, providing both developed and developing nations with economically efficient reporting tools to more effectively meet their obligations to international environment agreements and achieve conservation targets. As a result, governments and regulatory agencies can be encouraged to increase conservation or protective measures already in place or justify putting the environment higher on a government's agenda, perhaps creating initiative for identification of hopespots. Ultimately, the information obtained from the images can be used justify funding for restorative and/or corrective actions. Examples of ecosystems that benefitted from issues highlighted by satellite imagery and resulting restorative action include the Mau Forest Complex in Kenya, the Mesopotamia Marshlands in Iraq and the Islamic Republic of Iran and Lake Faguibine in Mali.

The global coverage of satellite imagery allows for transboundary issues to come to light, demonstrating changes occurring across certain borders and how the changes are affecting the associated countries. As shown in Box 4, for instance, as the water level of Lake Chad receded, Nigeria, Niger, Chad and Cameroon, in addition to the countries located in the Lake Chad basin, each lost a significant amount of an ecosystem essential for fishing and agricultural practices, albeit in varying proportions. The images used to illustrate the hotspot help to highlight the changes in each country and could serve as a tool for future management decisions. In the same way, satellite imagery can help to identify change in a surrounding or neighboring area that might have an impact on an area not in the immediate vicinity - e.g. the Merowe Dam, Sudan hotspot showing how dam construction can affect ecosystems tens or even hundreds of kilometres downstream.

Box 4. Lake Chad, Nigeria, Niger, Chad and Cameroon, Africa
Major Theme: *Climate Change and Atmosphere* ***Themes:*** *Wetlands; Water; Atmosphere and Climate*



Climate variability and increased water consumption by the area's inhabitants have changed the water balance within the Lake Chad drainage basin, and continue to do so. Since the early 1960s, rainfall over the basin decreased significantly while irrigation increased dramatically over the same period resulting in a 95% reduction in the lake's area. As these satellite images from 1973 and 2012 show, the surface area of the lake has declined dramatically.
Source: Adapted from UNEP, n.d.b; Images: Landsat, visualisation by UNEP/GRID-Sioux Falls

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The economic benefit of using imagery as a decision-support tool stems from the fact that some imagery, such as Landsat, is free for users to acquire, and the modeling processes that use the data have been known to add more value to the data. For example, the USGS, in cooperation with the United States Department of Agriculture (USDA) National Agricultural Statistics Service and the Iowa Department of Resources, used satellite imagery to model the relationship between land use, agriculture and dynamic nitrate aquifer contamination. The results of the modeling exercise revealed that by using information such as satellite imagery, the effeciency of agricultural production can be increased and nitrate-leaching estimates can be improved (Raunikar et al., 2013). The study estimated that the value of the information derived from imagery could be as much as US $858 million Â±US $197 million per year, corresponding with a current value of US $38.1 billion, Â±US $197 billion, for benefits extending into the foreseeable future.

Despite the numerous benefits of using imagery to detect and visualise environmental changes, a few challenges exist. Gathering adequate resources to first develop an accurate and compelling storyline can be difficult if recent and relevant information is not widely available. Moreover, due to the large file size of most raw satellite images, a robust Internet connection is necessary for download. Specific software is then needed to process and analyse the imagery, which can be costly. Some open-source programs can process imagery, but may require additional skills to operate or again, a robust Internet connection to download. Further, as mentioned previously, if one particular satellite cannot offer the spatial and temporal imagery needed, other types of imagery must be acquired. It can be a daunting task to gather images that are cloud-free, cover the entire area of interest and are time-appropriate for the change that is being described. Overall, the process of identifying, describing and illustrating a hotspot or hopespot can be laborious and lengthy, but ultimately the hard work should pay off with the benefit of creating awareness, encouraging restorative action and demonstrating progress.

As the planet continues to change to accomodate the growing global population, and as a result of natural processes, observing and mapping changes in an economically efficient, understandable and communicable way will be essential for improved environmental management. Hotspot and hopespot locations, illustrated with several satellite images, can serve as a method of mapping and tracking changes and restorative progress, as well as a basis for further actions to strive for a more sustainable future. Further, the accessibility of information will play a substantial role in global change studies as local level changes are brought to global audiences. UNEP plans to continue to aid in the accessibility of information as part of its mandate to continually review the state of the global environment with the identification of new hotspots and hopespots and the updates of existing ones with new information and imagery.

Acknowledgement

Written by: Lindsey Harriman[a]

Production and Outreach Team: Arshia Chander[a], Erick Litswa[b], Kim Giese[a], Lindsey Harriman[a], Michelle Anthony[a], Reza Hussain[a], Mwangi Theuri[b] and Zinta Zommers[b]

Special thanks to Ashbindu Singh[a,b], Ron Witt[c], Zinta Zommers[b], Theuri Mwangi[b], Arshia Chander[a], Frank Turyatunga[b], Jacqueline Alder[d], Andrea Salinas[e] and Shelley Robertson[f] for their valuable comments and review.

([a]UNEP/GRID-Sioux Falls; [b]UNEP/DEWA-Nairobi; [c]UNEP/GRID-Geneva; [d]UNEP-Marine and Coastal Ecosystem Branch; [e]UNEP/DEWA-LAC; [f]Munk School of Global Affairs, University of Toronto)

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