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Space Technologies for Monitoring and Protecting Biodiversity and Ecosystems

A Proposed New Thematic Priority for the United Nations Programme on Space Applications

I. Introduction

1. Biodiversity and the protection and conservation of ecosystems are of major importance in the framework of the post-2015 development agenda. Some of the proposed Sustainable Development Goals (SDGs) are directly addressing biodiversity and ecosystems.

2. The spatial variability of different hierarchical levels of natural habitats can be used as an indicator of the current state, distribution, temporal changes of biodiversity. The combination of various resolution levels of satellite sensors with organizational levels of ecosystems is one of the main ideas of applying earth observations in monitoring of biodiversity.

3. A wide range of solutions is enabled by space technology to support the management of biodiversity and ecosystems. In particular, Earth observations and positioning applications are being used in various biodiversity and ecosystems projects around the world. Some of these applications have been presented and discussed at past events organized under the United Nations Programme on Space Applications; however, there has never been a dedicated effort to address these increasingly important topics.

4. Changes in land cover affect global climate through the absorption and reflection of solar radiation, leading also to altered fluxes of heat, water vapour, carbon dioxide or other trace gases. Observing and monitoring these changes and fluxes over time on a regional and global scale, at daily and seasonal time intervals, as well as mapping of those land use and land cover changes on a regular basis are

all needed to determine biodiversity status and ecosystems dynamics. This in turn aids decision makers in defining mitigation and protection measures and in raising public awareness with regards to risks linked to biodiversity loss or overexploitation.

5. Several Member States have been requesting that the Office for Outer Space Affairs consider increasingly active involvement in space technology advocacy and applications for the biodiversity and ecosystems domains with possibly a more focused view on coastal and marine ecosystems due to the economic importance of coastal areas, in general, for most countries bordering the oceans and seas of the Earth.

6. Satellite imagery is perhaps the best source of monitoring biodiversity status, especially over large areas. Observations need to be extensive, regular and consistent to establish baselines and trends which is what satellite-based sensors can do the best. Most satellite observations, however, still have limited coverage and compatibility, because they are controlled by the diverse objectives of national space programmes. In many cases, satellite data are restricted or are not freely available.

7. In order to provide effective biodiversity monitoring, satellite remote sensing technologies are best applied together with Geographic Information Systems (GIS) technologies. One of the ways to assess biodiversity loss is through integrated mapping and indicator strategy, by collecting seasonal remote sensing data and applying classification systems and integrated mapping. Such procedures allow for the production of a set of indicators covering such aspects as landscape structure, ecosystem properties and threats to the protected areas.[1]

8. An open satellite data revolution certainly started when the United States Geological Survey (USGS) released, at no cost to the public, its entire Landsat archive which dates back to the 1970s and is the world's largest collection of Earth imagery. It led to other subsequent similar data releases as well as another revolution in imagery data processing and analysis tools. Production of large-scale, global mosaics of satellite imagery is no longer an extremely time-consuming process and can easily be distributed through online services as well. Developing countries could thus, more easily benefit from these products, even if they lack local adequate processing tools, hardware or software.

9. In the following sections, an overview of selected relevant organizations and institutions activating in the biodiversity protection and monitoring domain will be presented, also, considering the current use of space technologies in their work. Similarly, various space technologies and Earth observation sensors will be presented as they relate to or support ecosystems' monitoring and biodiversity protection. Finally, the role of the Office for Outer Space Affairs in this domain will be addressed, with a view to identifying possible activities with the potential to be most beneficial in observing and addressing global biodiversity issues.

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[1] S. Weiers et al. '*Mapping and indicator approaches for the assessment of habitats at different scales using remote sensing and GIS methods*' Landscape and Urban Planning 67 (2004) pp. 43-65

II. Select Institutions and Their Use of Space Technologies in Addressing Biodiversity and Ecosystems Management

10. In a first attempt the Office for Outer Space Affairs carried out a review of the ongoing multitude of programmes, projects, related conferences or workshops, and other activities related to biodiversity research and ecosystems management focusing on coastal and marine ecosystems, in relation to utilization of space technologies. However, this resulting list is by no means exhaustive, given the very limited access that the Office for Outer Space Affairs has to relevant conferences or workshops as well as to various communities of practice.

A. United Nations and Affiliated Entities

11. **The United Nations Environment Programme (UNEP)** is being the most important and natural partner for the Office for Outer Space Affairs in this domain. Various efforts are ongoing in monitoring endangered species, in combating poaching and environmental crime, in general, and in publishing print and online atlases of global change and environmental assessments using Earth observation data. UNEP is also closely linked with the Convention on Biological Diversity (CBD, www.cbd.int) and the Convention on Migratory Species (CMS, www.cms.int).

12. UNEP-affiliated or Cooperating Centers of specific interest to these domains are the World Conservation Monitoring Centre (**WCMC**) (www.unep-wcmc.org) or **GRID-Arendal** (www.grida.no).

13. WCMC is operating the Ocean Data Viewer (www.unep-wcmc.org/featured-projects/ocean-data-viewer), providing an overview and access to data important for the conservation of marine and coastal biodiversity such as data being collected from different sources including remote sensing data.

14. GRID-Arendal is supporting UNEP’s work on rapid assessments of environmental hotspots, in monitoring or reducing environmental crime, and in data visualization in general. The institution is interested in utilizing Earth observation data more frequently in these contexts.

B. Governmental and Intergovernmental Entities

15. The **National Commission for Knowledge and Use of Biodiversity (CONABIO)** is a Mexican permanent interdepartmental commission, created in 1992. Its mission is to promote, coordinate, support and carry out activities aimed at knowledge of biodiversity and its conservation and sustainable use for the benefit of society. It namely has a program aiming at monitoring ecosystems using remote sensing techniques (www.conabio.gob.mx/conocimiento/cambios_veg/doctos_ing/cambios_vegetacion.html).

16. **The United States Environmental Protection Agency (EPA)** supports various efforts in biodiversity and ecosystems and has often made use of space technologies in that context.

17. **The European Space Agency (ESA)** is member of several biodiversity related working groups, such as the GEO-BON (Group on Earth Observations Biodiversity Observation Network) ad-hoc working group where the Essential Biodiversity Variables that can be monitored by remote sensing will be defined. It also funds a series of projects to monitor ecosystems and biodiversity, among which, in cooperation with Ramsar (the international environmental convention on wetlands), the GlobWetland Africa project, aiming at facilitate the use of EO information by the wetland community, and develop an open-source toolbox to monitor the ecological status of wetlands.

18. **The European Union (EU)** funded a project named BIOdiversity multi-source monitoring System: from Space to Species (BIO_SOS). The main aim of the project is to develop the Earth Observation Data for Habitat Monitoring (EODHaM) system. The project involves consistent mapping and monitoring which implies a combination of pixels and object-based procedures, applying the land cover classification system of the Food and Agriculture Organization (FAO). The EODHaM system is automated with using the Remote Sensing and GIS Library (RSGISLib) software together with the Geospatial Data Abstraction Library (GDAL), and can use very high resolution (VHR) optical and hyperspectral data, with the ability to ingest data from any sensor (radar or LIDAR) at any scale.[2]

19. Large international bodies such as the **Committee on Earth Observation Satellites** (**CEOS**, www.ceos.org/) and more recently the **Group on Earth Observations** (**GEO**, www.geosec.org, www.earthobservations.org) have also established biodiversity-related working groups and experts teams, and organized various activities aiming at capacity-building, too.

20. The **French Institute for Research and Development (IRD)** collaborates with many countries and has a strong focus on environmental issues, using remote sensing, such as marine ecosystems management and tropical forest management: canopy monitoring, study and preservation of tropical forest biodiversity and valorisation of tropical forest ecosystems.

21. **The Indian Space Research Organisation (ISRO)** has various projects supported on Coastal Zone Studies, such as (www.isprs.org/proceedings/xxxv/congress/comm7/papers/235.pdf) or the Potential Fishing Zone (PFZ) Forecasting.

22. The **National Aeronautics and Space Administration (NASA) of the United States of America** has been instrumental in the release of the large Landsat archive, as mentioned above. In addition, a number of its space instruments support marine ecosystems and biodiversity research, further enabled by the free and open data policy.

23. The **NANSEN International Environmental and Remote Sensing Center (NIERSC)** based in St-Petersburg, Russia is a non-profit international research institute for environmental and climate research, focusing on the Arctic. It uses satellite observations for various topics, including for an environmental monitoring system in the ecosystems and oceanographic fields.

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[2] R. Lucas et al. '*The Earth Observation Data for Habitat Monitoring (EODHaM) system*' International Journal of Applied Earth Observation and Geoinformation 37 (2015) pp. 17-28.

24. **The National Oceanic and Atmospheric Administration (NOAA-CRCP) — Coral Reef Conservation Program** (http://coralreef.noaa.gov) supports related international efforts and UNEP activities. The programme provides coral reef managers, scientists and other users worldwide with data and information. Examples of space applications include the use of satellite-generated sea surface temperature data to forecast coral bleaching events.

C. Non-Governmental Organisations

25. **The Jane Goodall Institute** (www.janegoodall.org) implements various conservation, habitat monitoring and protection projects for great apes across the world, and uses Earth observation data and available visualization tools extensively. It has a dedicated Geographical Information System (GIS) and Remote Sensing (RS) Unit.

26. **The Wildlife Conservation Society (WCS)** (www.wcs.org/) invests resources worldwide in various conservation projects and related research. It has an extensive database of these efforts as well as data collections and is increasingly involved in utilization of space technologies including wildlife tracking. It is also an active supporter and animator of global expert mailing lists and resource pools such as Conservation Remote Sensing (https://groups.google.com/forum/#!forum/Conservation_RS).

27. **WorldFish** (www.worldfishcenter.org/) is a research organization that focuses on improving food security through sustainable management of fish resources. It collects information about items such as fish stock sizes by using satellite data and other available methods, with a focus on Africa, Asia and the Pacific region.

28. Another interesting project in the marine ecosystems domain is the **Hyperspectral Imager for the Coastal Ocean (HICO)** project (http://hico.coas.oregonstate.edu/). The Hyperspectral Imager has been installed on the International Space Station (ISS) Japanese Exposed Facility and provides imagery that can be used to develop a novel space-based environmental monitoring system to provide information for the sustainable management of coastal ecosystems such as monitoring phytoplankton, turbidity, and dissolved organic matter absorption.

29. **The Institute for Marine Remote Sensing (IMaRS), University of South Florida** (http://imars.marine.usf.edu/), has research activities focused on the analysis of digital data obtained by satellite and airborne sensors and on development of applications of the data on different scales. The institute primarily specializes in coastal processes of highly variable regions like the Gulf of Mexico and the Caribbean Sea.

30. The **Nees Institute for Biodiversity of Plants** of the University of Bonn, Germany, is involved in several biodiversity and biogeography projects, and part of the BIOTA AFRICA research network (http://www.nees.uni-bonn.de/research-/ecology-and-biogeography/biogeography-and-macroecology-biomaps/biota) aiming at the sustainable use and conservation of the biodiversity of the African continent. The BIOMAPS working group at the Nees Institute for Biodiversity of Plants in Bonn is focused on the continental patterns of plant diversity in Africa as a model

continent. It has established the International Biogeographical Information System on African Plant Diversity (BISAP).

31. The **NANSEN and Tutu Centre for Marine Environmental Research** (http://ma-re.uct.ac.za/nansen-tutu-centre/) is a cooperation between Norway and South Africa, under the management and financial control of the University of Cape Town. Its goal is to improve the capacity to observe, understand and predict marine ecosystem variability on timescales from days to decades, using among other techniques satellites observations.

32. Concerning wildlife monitoring, **Save The Elephants** is a non-profit organisation aiming at sustaining elephant populations and preserving the habitats in which elephants are found. They implemented an elephants real-time tracking project to monitor migration movements using GNSS technology. (http://savetheelephants.org/research/tracking-real-time-monitoring/)

D. Science Groups and Specialized Events

33. Various specific workshops and conferences are organized annually by expert groups and are also to be considered important sources for more knowledge in this domain.

34. One example is the **Zoological Society of London (ZSL)** symposium entitled “Remote Sensing for Conservation: uses, prospects and challenges” held in 2014. At the conference, a new open access journal, **Remote Sensing in Ecology and Conservation** (www.zsl.org/about-us/remote-sensing-in-ecology-and-conservation) was presented.

35. Another upcoming **EURISY** conference in Bari, Italy, in 2015 will address issues such as European peripheral and maritime regions and European Union (EU) support for Regions implementing EU coastal management directives as well as regional maritime strategies and challenges.

36. The **Land Use and Land Cover Change (LULC)** applications looking at forest loss, agriculture encroachment and loss of agricultural lands and other habitat loss are being developed by a large set of science groups, with frequent support from space agencies.

37. All the work listed above relies heavily on Earth observation data, and the range of tools and services developed are impressive, yet little known to many developing countries and their respective networks of experts. The Office for Outer Space Affairs could, therefore, join efforts in capacity-building and relaying science-based information to the public and especially to decision makers on such important aspects of biodiversity and ecosystems management.

III. Space Technologies and Sensors — Overview

38. The space technologies mainly used for biodiversity research and ecosystems management can be divided into two main types of instruments-carrying satellites: imaging satellites or Earth observation satellites and Global Navigation Satellite Systems (GNSS).

A. Imaging satellites instruments (sensors)

39. There exists a large variety of instruments and technologies or techniques aimed at observing the Earth, all of which can be suitably used to monitor biodiversity and ecosystems. The following review addresses only a few of these which are considered to be more relevant. More detailed information about imaging satellites and instruments can be found at: www.eohandbook.com/eohb2014/sat_earth_obs_vis_ir.html.

A.1. High-Resolution Optical Imagers

40. High Resolution Optical Imagers are commonly used for Earth observation. They cover spectral bands in the visible and infrared range (0.4 μm to 3 μm). Typically, High Resolution Optical Imagers are both panchromatic and multispectral, which means that they can operate in a single waveband and/or multiple wavebands. Spatial resolution of these devices can vary between 0.3 m and 100 m. Similar to other imagers, the High Resolution Optical Imager is restricted to the solar-illuminated side of the Earth as well as by weather conditions.[3]

41. These instruments are mainly used to provide valuable data about land surfaces such as forests, agriculture areas, and wetlands and to support environmental monitoring and planning. These instruments allow users to assess damage which is associated with natural hazards by comparing the images taken before and after a natural catastrophe or disaster and by extracting geospatial data with tools such as GIS.

42. Optical imagers, in general, are also used to improve vegetation classification methods and for other agricultural and forestry purposes, based on the retrieval of the vegetation reflectance from the optical images, which differ according to various bio-parameters enabled to classify the vegetation into established categories.[4] Moreover, they enable early detection of forest degradation and deforestation and the conduction of natural resource assessments.

43. Finally, they allow wildlife tracking applications. For instance, the World Wildlife Fund is using high-resolution imagery from DigitalGlobe's WorldView-2 (or more recently WorldView-3) satellite to create maps of conservation areas in southern Africa. The maps identify the corridors where elephants, buffalo and other animals travel as well as the local roads and villages. World Wildlife Fund officials plan to provide these maps to local community leaders to show the location of popular wildlife corridors with respect to their infrastructure. The goal is to minimize conflict between people and animals.

44. Tracking wildlife with an optical imager has an advantage over a field work by being less time-consuming, requiring less manpower, being more economical, and not disturbing animals. However, it has its limitations in that animals can only be detected in open areas and can often not be identified due to limited resolutions.

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[3] Ward, S. (2012). *The Earth Observation Handbook*. Noordwijk: ESA communication.

[4] Koetz, B., Arino, O., & Paganini, M. (2013). *DUE preparatory activities for Sentinel 2 exploitation*. Noordwijk: ESA communication.

A.2. Hyperspectral Imagers

45. A Hyperspectral Imager is a new passive type of Earth observation instrument developed in the early 1990s, which covers a large number of narrow spectral bands in the visible, visible infrared, shortwave infrared, mid-wave infrared and thermal infrared (currently under development). The Hyperspectral Imager allows us to make images of features in continuous spectra, including between 100 and 300 wavelength bands, by measuring radiances. This instrument can identify surface materials for a large region by comparing the image spectra created by this instrument to ground-based sample spectra. Hyperspectral Imagers may replace panchromatic and multi-spectral imagers in the future, but scientific and developmental challenges still exist in the current stage.

46. The Hyperspectral Imager has a spatial resolution of approximately 30m or less. It relies on solar illumination as well as weather conditions similar to panchromatic and multi-spectral imagers. The main purposes of this type of instrument are to analyse soil moisture content by applying thermal infrared (6 µm-15 µm), map soil and minerals by applying mid-wave infrared to thermal infrared (3 µm-15 µm), and map vegetation by applying visible to shortwave infrared (0.4 µm-3 µm). The hyperspectral imaging can discriminate and quantify the plant pigments and estimate the water content and dry matter content of the plants: whereas, classical vegetation indices such as NDVI, derived from multi-spectral sensors, usually cannot. These biochemical parameters are essential for monitoring desertification, evaluating the contribution of the vegetation cycle carbon, studying biodiversity, controlling the effects of agriculture on the environment, and preventing forest fires.

47. Regarding hydrological applications, the Hyperspectral Imager can also analyse and map water quality, determine chlorophyll-concentration, and detect coastal and coral reef habitats by applying visible to near infrared (0.4 µm-1.3 µm). Moreover, it is used for detecting water pollutants such as chemical dumps or oil spills within the ocean by applying a similar infrared (0.4 µm-0.9 µm) as well as the environmental impact such as on water quality, plants and animals. In addition, it can detect algal blooms which deplete the oxygen levels required for organic life (0.4 µm-0.9 µm).[5] Finally, it can map the coastal concentration of inorganic and organic particles as well as dissolved water substances.

48. The knowledge of water quality such as the concentration of chlorophyll that can be provided by the Hyperspectral Imager, combined with the knowledge of the sea surface temperature is a benefit for modern fishery, as certain types of fish are strongly attracted to water with a specific concentration of chlorophyll and water temperature.

A.3. Imaging Multi-spectral Radiometers (Visible, Infrared or Passive Microwaves)

49. Visible and Infrared Multi-spectral Imagers are instruments that provide accurate spectral information about Earth's atmosphere and surface with spatial resolutions from just a few tens of metres up to several thousands of kilometres with a swath width from several hundred to thousands of kilometres. In order to derive

[5] Klemas, V. (2009). *Sensors and Techniques for Observing Coastal Ecosystems*. Newark: Springer.

surface parameters, however, the effects of atmospheric absorption have to be taken into account.

50. The Visible/Infrared Multi-spectral Radiometers provides information on global vegetation and its variation, classification and seasonal monitoring of global vegetation types. The Advanced Very High Resolution Radiometer sensor (AVHRR) aboard National Oceanic and Atmospheric Administration (NOAA) satellites and the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) can identify droughts areas. Both the instruments AVHRR and the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) on board the Terra satellite use the thermal infrared (TIR) which provides grey level images generated by relative radiant temperatures. Light tones correspond to warmer temperatures and dark tones to cooler temperatures.

51. Moreover, those radiometers are used to monitor the ocean colour imagery such as the Moderate Resolution Imaging Spectroradiometer (MODIS), as they enable a large-scale analysis of oceans and coastal zones. Other data that may be inferred from ocean colour measurements include information about suspended matter, biological productivity, marine pollution and water dynamics in coastal zones. Ocean colour imagery can also be used in support of fisheries management or protection, for example, through the identification of biologically rich areas.

52. Passive Microwave Multispectral Radiometers are passive instruments which can penetrate clouds and have the ability to work in all weather conditions, as well as during day and night time. The Microwave Radiometer instrument uses channels between 1 GHz and 40 GHz as well as between 80 GHz and 100 GHz. An advantage of the Microwave Radiometer is that it can penetrate certain surfaces as well as probe the surface dielectric properties. This capability is especially useful for identifying vegetation, soil, sea ice and snow. The Microwave Radiometer can produce accurate spectral information but has a lower spatial resolution compared to alternative instruments. It is why these instruments are applied mostly to global analysis purposes.

A.4. Scatterometers

53. The Scatterometer is an instrument which operates in a microwave wavelength and is, therefore, independent of weather conditions. The instrument is active, thus it transmits radar pulses towards selected destination which gets backscattered toward the instruments receiver. The strength of the backscattered energy is dependent on the targets dielectric properties but also on its roughness.

54. The main purpose of the Scatterometer is to measure the wind speed and direction over the ocean surface, which is dependent on the size of the surface ripples on the ocean and their orientation with respect to the propagation direction of the pulse of radiation transmitted by the scatterometer.

55. It provides a large number of terrestrial applications such as soil moisture and rainforest monitoring. For instance, the Advanced SCATterometer (ASCAT) sensor on board the Metop-A satellite is an active microwave radar instrument operating at 5.255 GHz (C-band) and using vertically polarized antennas. It can observe subcanopy and subsurface climate-related features and has a rapid global coverage, day and night under all-weather conditions.

A.5. Light Detection and Ranging (LIDAR)

56. Light Detection and Ranging (LIDAR) is an active remote sensing technique based on measuring the round-trip time of a laser pulse between a sensor and the test surface. The pulse is on the order of a few nanoseconds and most often takes the form of a pseudo-Gaussian. The wavelength of the laser beam is equal to 1064 nm. There are two systems: the multi-echoes LIDAR that records several energy peaks for the same laser pulse and the full wave LIDAR return which records the entire reflected laser wave. If the surface is a canopy, the returned wave consists of a series of peaks containing more or less energy, which characterizes the 3D structure of the target. In recent years, LIDAR has provided high precision altimetry for land surface topography and unique information on the structure of vegetation cover.[6] It can focus on vegetation canopy structure and provide estimates of global biomass and carbon stocks and also fractional forest cover. For instance, the space borne Geoscience Laser Altimeter System (LiDAR GLAS) on board of ICEsat provides canopy top elevation, ground elevation and vegetation height.

A.6. Imaging Microwave Radars

57. Imaging Microwave Radars use backscattered signals of frequencies between 1 GHz and 10 GHz and provide microwave images of Earth's surface with a high spatial resolution of 10 m to 100 m with a swath width between 100 km and 500 km. There are two categories of radars: real aperture radars and synthetic aperture radars (SAR). They can be either monostatic, which is a conventional configuration, or bistatic, which means that the transmitter and receiver are located on two different antennas. Both of them work through clouds either day or night, penetrate vegetation, depending on the wavelength band used, and provide dielectric properties.

58. Their main biodiversity-related applications are the detection of ocean oil slicks or illegal degassing and the detection of vegetation type and cover provided by the different responses of various types of vegetation, according to the emitted wavelength. For example, the satellite Sentinel-1, which has a free data distribution policy in the Sentinel and the European Union COPERNICUS framework, has a spatial resolution of 5 m and may be used for forestry, agriculture and flood monitoring. The radar sensors can also be used to evaluate forest characteristics and to estimate biomass volumes.

59. It is also possible to create Digital Elevation Models (DEM) by interferometry using two radar images. A DEM is created using the differences in the phase of the waves returned to the receivers. The digital canopy model (DCM) is then obtained by subtracting the digital terrain model (DTM) from the DEM. Free DEM data can also be obtained from the Shuttle Radar Topography Mission (SRTM) data with a spatial resolution of 30 m. TerraSAR-X add-on for DEM (TanDEM-X) pair of satellites also provides DEM products at a spatial resolution of up to 12 m.

60. Moreover, the polarization of waves is another property of radar technology and is very useful for vegetation applications. Polarization can provide various

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[6] Mallet, C., Bretar, F., A, C., Bailly, J., & Jacome, A. (2009). *Terrain surfaces and 3-D landcover classification from small footprint full-waveform lidar data: application to badlands*. Saint-Mande: Hydrology and Earth System Sciences.

information used for land cover classifications and soil moisture. The polarization of waves enables measuring the Normalised Difference Vegetation Indices (NDVI), one of the main parameters used to assess the state of vegetation and crop yields.

B. Global Navigation Satellite Systems (GNSS)

61. The Global Navigation Satellite System receivers, either GPS, GLONASS, Galileo, BeiDou, or other systems, can be used to track wildlife. Indeed, they enable significant advances in wildlife ecology by providing accurate, regular and frequent estimates of movement and changing distributions of many rare and less rare animal species. This not only allows the study of wildlife behaviour but also protects it from poaching because knowing the position of herds accurately and frequently enables competent authorities to deploy anti-poaching patrols.

62. GNSS equipment has become more and more essential in all aspects of life and remains an important data and information source to improve mapping accuracy, in general, wildlife tracking, monitoring, and combating environmental crime. Therefore, GNSS applications are expected to further grow in the near future, leading to an increased need of building capacity and raising awareness among users.

IV. Programme on Space Applications — Related Activities

63. A thorough review of past activity reports of the Programme on Space Applications for the last ten years reveals a multitude of workshops, international meetings and capacity-building activities that already addressed aspects of biodiversity protection and ecosystems monitoring as well as the need for more availability of Earth observation data.

64. The United Nations/Austria/European Space Agency series of symposiums on space applications to support the Plan of Implementation of the World Summit on Sustainable Development, held in Austria, in 2003, 2004 and 2005 (A/AC.105/844), noted that satellite-obtained data and derived information could support fishermen by providing valuable information on the coastal environment and coastal and ocean resources. It also observed that high-resolution satellite data could be effective in crop planning, forecasting and monitoring.

65. The United Nations/International Astronautical Federation Workshop on the Use of Space Technology for Water Resources Management in Spain in 2006 (A/AC.105/878) discussed space technology support for biomass estimation, while the United Nations/Morocco/European Space Agency International Workshop on the Use of Space Technology for Sustainable Development in Morocco in 2007 (A/AC.105/898), considered sustainable development and management of coastal and marine ecosystems and aquaculture as well as crop yield forecast. These workshops already identified the importance of spatial data infrastructures and data sharing in general for biodiversity and ecosystems monitoring.

66. Two workshops in 2007, namely the United Nations/Viet Nam/European Space Agency Regional Workshop on the Use of Space Technology for Forest Management and Environmental Protection in Viet Nam (A/AC.105/906), and the

United Nations/Argentina/Switzerland/European Space Agency Workshop on Sustainable Development in Mountain Areas of Andean Countries in Argentina (A/AC.105/913), highlighted the need for mountain monitoring and accurate forest cover maps derived from Earth observation data, which is an essential requirement for identifying and mitigating existing and potential threats to forests. Such maps, in combination with regular satellite imagery coverage, could be used to monitor the sustainability of forest ecosystems and estimate forest biomass according to country, ecological zone, climate region or other terrestrial characteristics.

67. The 2008-2011 period saw a number of workshops addressing atmospheric monitoring, agriculture and food security again. The Andean Ecosystem was addressed at the United Nations/Peru/Switzerland/European Space Agency Workshop on Integrated Space Technology Applications for Sustainable Development in the Mountain Regions of Andean Countries in Peru in 2009 (A/AC.105/968). The United Nations/International Astronautical Federation Workshop on Global Navigation Satellite System Applications for Human Benefit and Development in Prague, Czech Republic, in 2010 (A/AC.105/984) benefitted from a presentation on the CarbonSat initiative constellation, aimed at responding to the need for an international integrated carbon cycle monitoring programme.

68. More recent Programme on Space Applications activities include the United Nations/Pakistan International Workshop on Integrated Use of Space Technologies for Food and Water Security in Pakistan in 2013 (A/AC.105/1054), discussing data availability for soil erosion mapping, agriculture optimization and introducing the SERVIR Himalaya programme which focused on mountain biodiversity and ecosystems topics. At this event, the participants agreed that natural ecosystems play a vital role in human subsistence.

69. At the United Nations/International Astronautical Federation Workshop on Space Technology for Socioeconomic Benefits in Canada in 2014 (A/AC.105/1081), it was recognized that space-related technologies, information and services were extremely useful in areas such as the ocean environment and the interaction of oceans with land and the atmosphere for monitoring sea traffic and ice conditions at northern latitudes, controlling illegal fishing and fighting sea piracy. Space assets provided unique capabilities in the observation of oceans and enabled communication and navigation by ocean travellers.

70. During the 56th Session of the United Nations Committee on the Peaceful Uses of Outer Space, the delegation from Nigeria made a statement which emphasized the importance of marine ecosystems and the use of space assets to safeguard fish resources and the health of ecosystem waters, coastlines and mangroves.

71. Numerous indications, as presented above point to the benefits of space technologies for biodiversity and ecosystem protection and monitoring. As ongoing efforts of the United Nations system in addressing the Sustainable Development Goals directly refer to biodiversity and ecosystems, the Office for Outer Space Affairs is also increasing its focus on applications of space technologies in this field. It will bring its long-time expertise in these technologies as well as its related capacity-building experience to the service of the Member States again.

72. In direct connection with capacity-building and related workshops, and based on identified requirements from various States or institutions, the Office for Outer

Space Affairs will also consider building the internal capacity and required connections to assist with such requirements, to mediate or provide analysis using space-based information for various biodiversity monitoring and protection efforts, in support of Member States and of other above-mentioned partners.

73. As a result, the Programme on Space Applications is currently working together with the Government of Kenya to organize the United Nations/Kenya Workshop in November 2015 to specifically address the growing demand for space-based information and space-based technologies for biodiversity monitoring and wildlife management. The Office for Outer Space Affairs will take the opportunity at the Workshop to also work with participants in defining the future role of the Programme on Space Applications in the areas of biodiversity and ecosystems.

V. Conclusions

74. Biodiversity and the protection and conservation of ecosystems will be of major importance on the Post-2015 Development Agenda. Various Sustainable Development Goals will relate to biodiversity and ecosystems in general and will require specific access to reliable, frequent and open geospatial data, in particular, Earth observation data.

75. In order to raise awareness of and to pursue the benefits of space technology and its applications in the areas of biodiversity and ecosystems, the Office for Outer Space Affairs would like to introduce monitoring and protecting biodiversity and ecosystems as a new thematic priority within the framework of the United Nations Programme on Space Applications.

76. Member States and their research institutions are invited to take part in activities carried out under this newly proposed thematic priority. The Office for Outer Space Affairs welcomes support, comments and suggestions on the implementation of the future activities.