THE HYPERSPECTRAL EARTH OBSERVATION SATELLITE
ENMAP – PLATFORM AND PROJECT STATUS

The EnMAP satellite consists of both a spacecraft platform and a payload. The in-orbit proven platform provides a very suitable and cost-effective solution for accurate, high-resolution Earth observation. Key advantages are the modular and flexible configuration, a highly accurate attitude control system and a high-rate payload data processing chain including on-board storage and downlink capability.

The EnMAP payload, the Hyper Spectral Imager (HSI), is accommodated on top of the spacecraft bus in a manner to provide maximum thermal and structural de-coupling. This accommodation supports the demanding stability and thermal requirements of the optical system and enables parallel assembly and integration of both payload and platform.

Key figures of the EnMAP satellite bus are:

- **Dry mass (approx.): 553 kg (incl. margin)**
- **Propellant mass: 59 kg**
- **Overall Volume Bus (approx.): 1.2 x 1.3 x 1.8 m^3**
- **Solar Panel: body mounted, ~6,1 m^2, EOL 970 W @33,4V**
- **In-orbit storage: 512 Gbit (EoL)**
- **X-band downlink: 320 Mbit/s**

In 2015 the EnMAP platform entered the integration phase at OHB System AG. After completion of mechanical assembly and OCS testing the platform was transferred to OHB's "Optics and Science" center at the Oberpfaffenhofen site in May 2017 for further integration and test, and finally the assembly with the optical payload.

EnMAP: Development on behalf of the German Space Agency DLR with funds of the German Federal Ministry of Economic Affairs and Energy under grant No. 50 EP 0801.

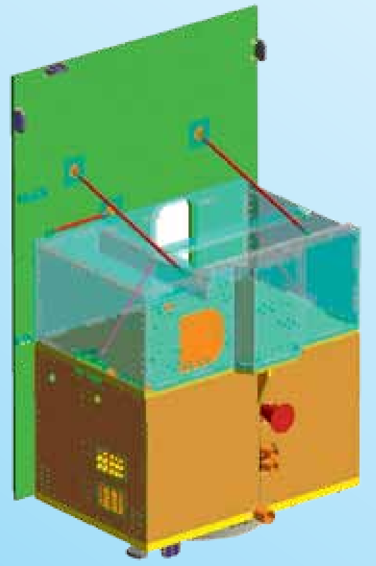
EnMAP IOU Flight Structure under dedicated Installation MGSE

The EnMAP Space Segment had successfully completed its Critical Design Review in October 2012 and is in ongoing manufacturing, assembly, integration and test phase since then. Complementary, the EnMAP Ground Segment has finished its Delta Critical Design Review in July 2016.

With the EnMAP telescope, the first complex main module of the EnMAP instrument has been already completed, whilst fully meeting its demanding performance requirements.

Since Q3 2016 the IOU (Instrument Optical Unit) structure is under flight integration with the pre-assembled optical elements (mirrors and prisms) in the newly created ISO-5 OHB clean room, forming the EnMAP spectrometer.

In parallel, the flight electronics units - in particular the two cameras (SWIR and VNIR) - are manufactured by the vendors, to be integrated and fine aligned in the IOU structure.


System overview (payload transparent, platform solid)


Accommodation of EnMAP platform

We. Create. Space.


We. Create. Space.

About OHB System AG

OHB System AG is one of the three leading space companies in Europe. It belongs to the listed high-tech group OHB SE, where around 2,800 specialists and system engineers work on key European space programs. With two strong sites in Bremen and Oberpfaffenhofen near Munich and more than 35 years of experience, OHB System AG specializes in high-tech solutions for space. These include small and medium-sized satellites for Earth observation, navigation, telecommunications, science and space exploration as well as systems for human space flight, aerial reconnaissance and process control systems.

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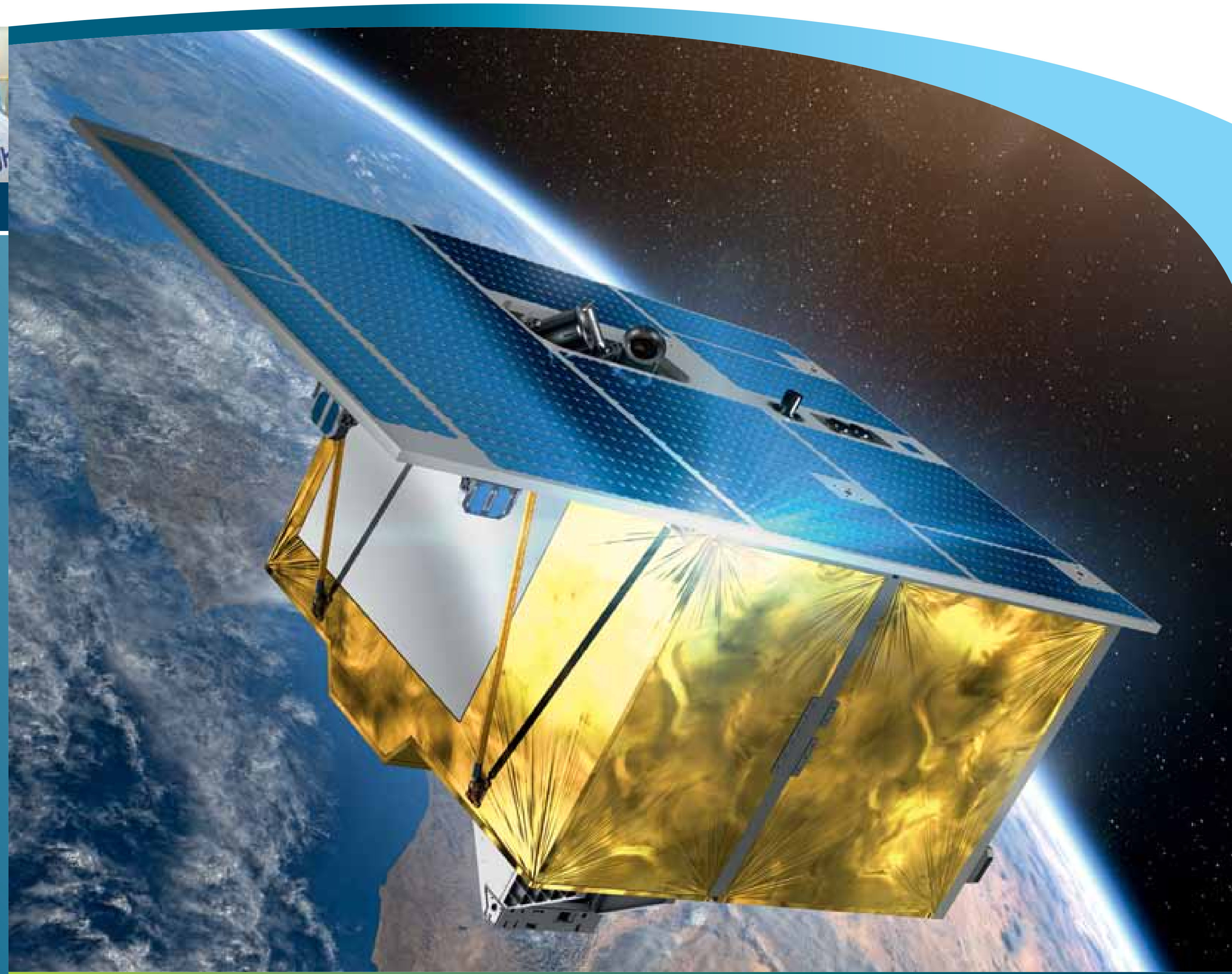
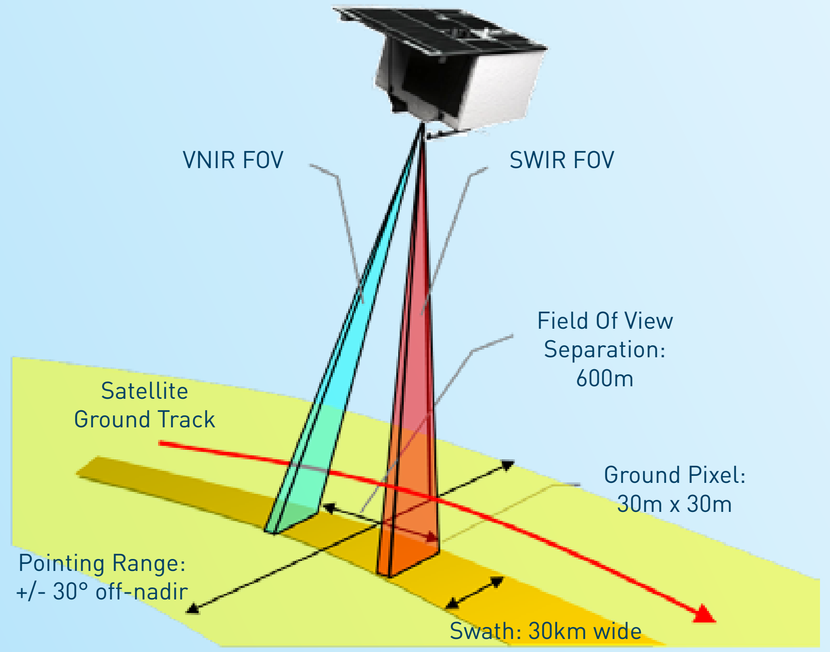


SPACE SYSTEMS

EnMAP

The Hyperspectral Earth Observation Satellite

THE HYPERSPECTRAL EARTH OBSERVATION SATELLITE
ENMAP – ENVIRONMENTAL MAPPING AND ANALYSIS PROGRAM



Representation of an EnMAP overpass

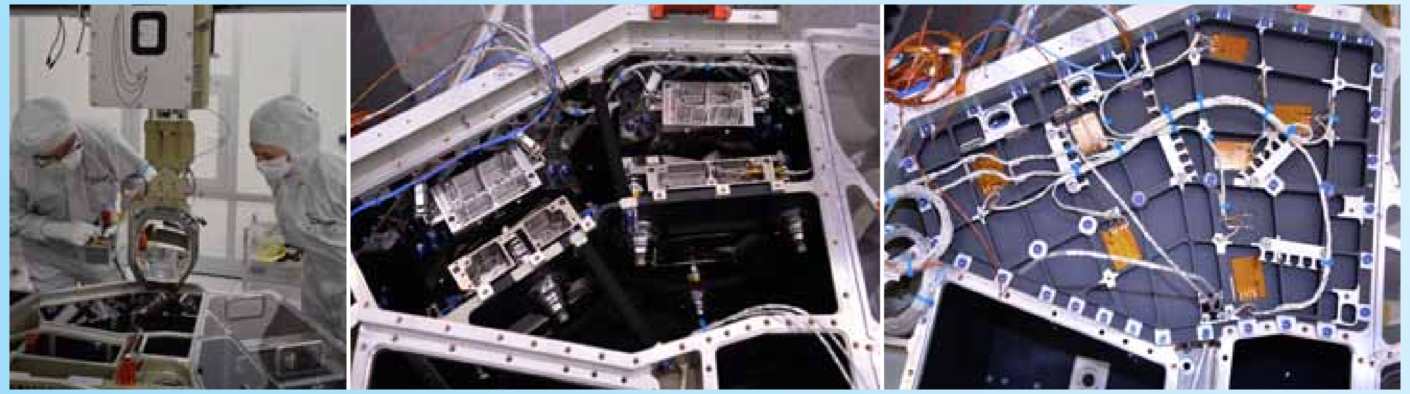
Complementary Global Data & Applications for Environmental Analyses

- German hyperspectral satellite mission with 244 measurement channels in the broad spectral range of 420 nm to 2450 nm
- Ascertainment of global ecological system parameters as well as biophysical, biochemical and geochemical variables
- Generation of innovative high-quality data products for improved models and for enhanced understanding of global biosphere and geosphere processes
- Data processing chain development for future commercialization and operational services
- Scientific Prime: Helmholtz-Zentrum Potsdam Deutsches GeoForschungsZentrum,
  Industrial Prime: OHB System AG,
  Ground Segment: DLR-DFD / DLR-GSOC.

The German Aerospace Center (DLR) entrusted OHB System AG as system prime with the German satellite mission EnMAP (Environmental Mapping and Analysis Program). The prime contract for the realization and launch of this technically challenging satellite covers the following mission aspects:

- Space Segment including the satellite bus as well as integration and test of the entire satellite
- Development and manufacturing of the payload: a sophisticated hyperspectral instrument
- Procurement of the flight opportunity including launch support and preparation; and the launch itself.

Instrument Optical Unit structure integrated with the pre-assembled Mirrors and Prisms, forming the EnMAP Spectrometer



MISSION PARAMETERS, PERFORMANCE AND HYPERSPECTRAL DATA
THE SATELLITE MISSION AND CLASSIFICATION OF MEASURING DATA

Mission parameters for EnMAP

Orbit	
• Sun-synchronous	11:00 h LTDN
• Altitude	642 km
• Inclination	98°
• Repeat cycle	27 days, 398 revolutions
Imaging concept	
• "push-broom" with 30 km swath width, pointing feature ±30°	
Target revisit time (pointing angle)	4 days (±30°)
Maximum ground coverage	5,000 km x 30 km per day
Data storage capacity	512 Gbit
Data downlink rate	320 Mbps via X-Band
Instrument Mass	360 kg
Instrument power consumption	< 300 W
Channels/Bands	
• VNIR: 420 – 1,000 nm (up to 99 bands)	
• SWIR: 900 – 2,450 nm (up to 163 bands)	
Satellite total mass	< 970 kg
Pointing	
• Accuracy	better than 500 m
• Knowledge	better than 100 m
Life time	5 years

Performance parameters for EnMAP

Mean SSI (Average Spectral Sampling Interval)	
• VNIR: 6.5 nm	
• SWIR: 10 nm	
Spectral calibration accuracy	
• VNIR: 0.5 nm	
• SWIR: 1 nm	
Ground resolution (GSD)	30 m x 30 m
Geolocation knowledge	< 100m
SNR at reference radiance	
• Signal to noise at reference conditions (R=0.3, 30° Sun-Zenith Angle) 500: 1 @ 495 nm (VNIR) 175: 1 @ 2,200 nm (SWIR)	
Radiometric resolution	14 bit
Radiometric accuracy	3,5 %

Performance

Fig. 1 shows EnMAP, characterized by resolution capability and number of spectral bands compared to other multi- and hyperspectral systems. EnMAP enables the global retrieval of ecosystem parameters with high spectral and spatial resolution with a simultaneously high repetition rate. It provides unique data which is due to its outstanding performance compared to all existing similar satellite systems. The hyperspectral data of EnMAP not only provide new answers to current scientific problems; but also have a huge potential for several future service applications.

EnMAP Data Sets

Fig. 2 (left) shows measuring data of a multispectral sensor, which gives little opportunity for identification and differentiation of materials (figure shows mineral example). In comparison, Fig. 2 (right) shows an example of the respective hyperspectral measurement signals (spectra).They are clearly differentiated and enable a definite diagnosis and improved classification of the individual materials. This allows new analytic approaches that were so far not possible with multispectral data.

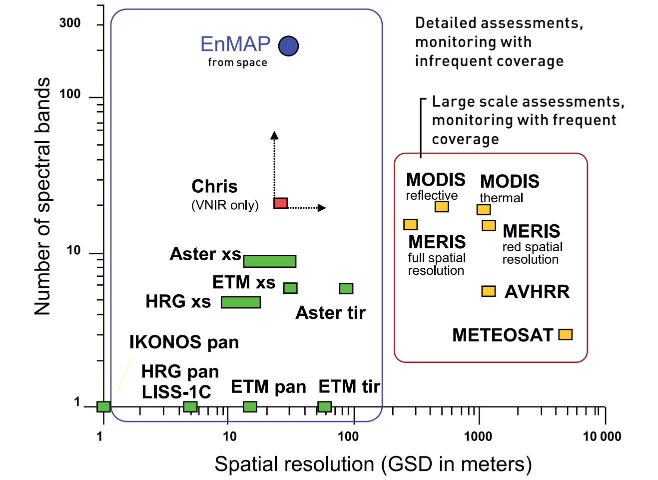


Fig.1: Description of the EnMAP performance compared to other multi- and hyperspectral systems

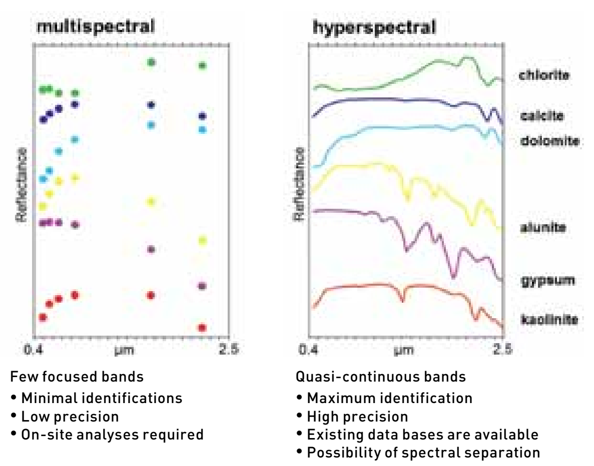
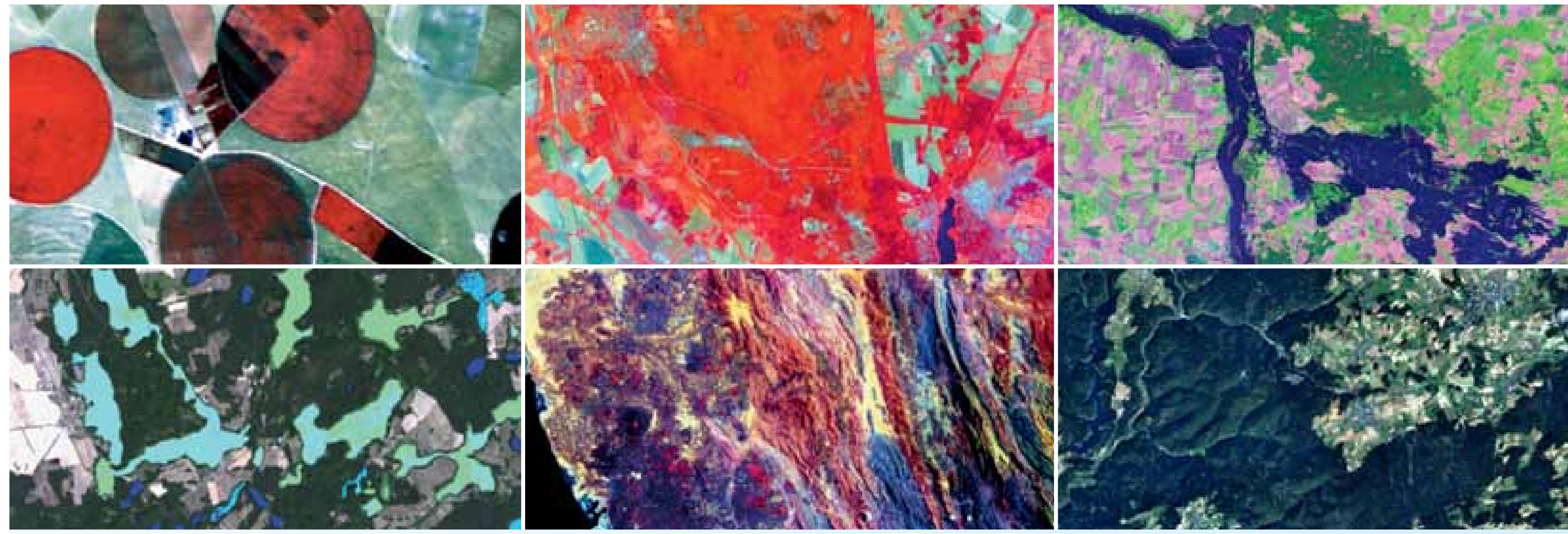


Fig. 2: Comparison of multispectral and hyperspectral measuring data

ENMAP: SCIENCE AND MARKET POTENTIAL
SCIENTIFIC AND COMMERCIAL APPLICATIONS

EnMAP is a user-driven mission and thus accordingly generates a data base for detailed analysis and, consequently, a better understanding of the processes on and above the surface of the Earth. The interaction of science and commercial users within the EnMAP user community will strengthen both the science and the value adding industry. Thus, they can adopt an international pathfinder role in the forward-looking optical remote sensing sector. Important fields of application and related challenging questions addressed by the members of the EnMAP Core Science Team (ECST) are shown in the following examples:



Land use / land cover changes and land surface processes

- Where and to what extent and rate do land degradation processes (desertification, ground erosion, salinization, soil acidification and others) and land use / land cover changes (deforestation, urbanisation and others) occur from local to global scale?
- How can land degradation be reduced or prevented in view of food security and environmental sustainability?
- What are the driving forces, anthropogenic and non-anthropogenic, for changes in land use / land cover and land surface characteristics?

Biodiversity and ecological stability

- What is the spatial pattern of ecosystem and diversity distributions from local to global scale?
- How do ecosystems change over time in their composition and health? (e.g., in the context of the European habitats directive)
- How are ecosystem processes and services being altered by human activities or natural causes and how can harmful consequences of ecosystem degradation be reduced or prevented?

Geohazard and risk assessment

- Which areas are prone or susceptible to geohazards such as landslides, floods and others?
- Which land use characteristics affect the vulnerability to geohazards and how can they be mapped and monitored?
- In case of a natural disaster, which areas are to what extent affected and how can this information be provided for short-term coordinated emergency response?

Water availability and quality

- Which areas are affected by water scarcity and water quality problems on a local to global and a seasonal to decadal scale?
- How do climate change and human activities such as intensive agriculture, water-demanding industries and high population density exacerbate water scarcity problems?
- How is inland and coastal water quality affected by land use change, climate change, inland water and coastal zone management and other factors?

Natural resources

- How can natural resources such as mineral deposits, energy sources (oil, gas), ground water sources and others be explored and managed in a sustainable way?
- What impact do human activities such as industry, mining, agriculture and others have on natural resources?
- How can environmentally harmful consequences such as water/air pollution, land contamination, mine waste and others be tracked, monitored and managed in order to conserve and sustain natural resources?

Climate change impacts and counteractive measures

- How does climate change affect state, composition and seasonal cycles of terrestrial and aquatic ecosystems?
- What measures can effectively combat climate change and how can their implementation be monitored? (e.g., reducing emissions from deforestation and forest degradation (REDD), carbon emission in forests and wetlands).