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Building the generativity of data to support the dynamics of multiple ecosystems: the case of Earth-observation data

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Abstract

The potential of data in generating multiple usages for a large variety of actors has been largely acknowledged by practitioners and researchers. However, this so-called ‘generativity’ potential is not an intrinsic property of data but needs to be built and sustained through dedicated efforts. Given the high heterogeneity and unpredictability of potential data usages, it seems increasingly difficult for data producers or data users to support such efforts on their own in a long-term perspective. Based on multiple case studies in the Earth observation context, our study especially unveils the existence of specific economic actors, coined ‘data generativity builders’, that act as innovation intermediaries to ensure a continuous and repeated transformation of data-usage pairs, involving specific forms of brokering, configuring and facilitating actions: they act as a buffer zone between the different ecosystems related to data production and data usages, ensuring some forms of circulation without creating direct dependences (*brokering*); they continuously design and redesign data-usage pairs, not only focusing on recontextualizing data for a new usage but also building a generic information core common to multiple usages (*configuring*); they create spaces for others to act, especially by identifying relevant capacity building actions through dedicated investigations on the specificities of each usage context (*facilitating*). This study offers interesting perspectives on how to unleash the potential of data in complex ecosystems of actors, going beyond a simple valorization logic.

I. Introduction

In recent years, the development of internet, new sensors, and computational means has dramatically increased the flow of data in almost every business, industry and research area. This phenomenon has been largely described as “digitalization” (Björkdahl and Holmén, 2019; Cappa et al., 2021), or “big data” (Bharadwaj and Noble, 2017; Blackburn et al., 2017; Chen et al., 2012). Scholars have extensively emphasized the potential of data in generating a number of usages for a large variety of actors spanning heterogeneous sectors. As highlighted by research in information systems, digital artifacts are characterized by their ‘open-endedness’, or ‘unboundedness’, insofar as data are perpetually ‘editable’ and can continuously generate new usages, different from what they were initially produced for (Aaltonen and Tempini, 2014; Kallinikos et al., 2013; Yoo et al., 2012, 2010). Data are thus associated with a certain ‘generative’ capacity, defined as “a technology’s overall capacity to produce unprompted change driven by large, varied, and uncoordinated audiences” (Zittrain, 2006). These properties result in a distributed organization logic, where both devices and knowledge associated with data are distributed across heterogeneous disciplines and communities (Kallinikos et al., 2013; Yoo et al., 2012, 2010).

In the last fifteen years, specific efforts have been made to support the circulation of data beyond the existing boundaries of organizations or sectors, especially through the development of dedicated ‘open data’ approaches. Such efforts consist in making data open and free to all, mainly involving the release of data by public actors (e.g. Berrone et al., 2016; Charalabidis et al., 2018; Zuiderwijk and Janssen, 2014), but also by private actors, e.g. in the pharmaceutical industry (Perkmann and Schildt, 2015). In this context, both researchers and practitioners have underlined a number of barriers and challenges to data ‘liquidity’ (Jetzek, 2016; Manyika et al., 2013), e.g. technical issues related to the identification, editing, formatting and sharing of data (Barry and Bannister, 2014; Janssen et al., 2012), but also issues in developing usages once data are released as users might not be aware or competent enough to use data on their own (Janssen et al., 2012; Smith and Sandberg, 2018; Zuiderwijk et al., 2012). Recent research has more specifically underlined the potential difficulties for SMEs in leveraging open data, shedding light on strong capacity requirements in terms of data acquisition, assimilation, transformation and exploitation (Huber et al., 2020). These challenges show that generativity is not an intrinsic property of data and rather needs to be designed through dedicated efforts, that are all the more important as the potential beneficiaries of data might be highly unfamiliar with them.

This paper proposes to investigate the mechanisms involved in designing the generativity of data, i.e. their capacity to We address this question through a multiple case study approach, digging into the case of Earth observation data where specific efforts are made to support the development of multiple usages among highly heterogenous ecosystems. To further describe the mechanisms involved in generativity building, we propose an analytical framework by

taking into account the specificities of data compared to other types of technology and leveraging the literature dealing with innovation intermediaries. Our study especially unveils the existence of specific economic actors, coined 'data generativity builders', that play a crucial role in supporting the continuous development of data usages in multiple and heterogeneous ecosystems.

II. Theoretical background

To better understand the efforts at stake when expanding data usages, we first rely on research in information systems that has made a specific effort in conceptualizing properties of data. We then precise our analytical framework based on an important stream of works in innovation management research describing the actions of "innovation intermediaries" that support distributed innovation processes among heterogeneous stakeholders

1) Conceptualizing the process of developing data usages

Expanding previous works on characterizing digital artifacts (Kallinikos et al., 2013; Yoo et al., 2012, 2010), a growing stream of research in information systems has recently focused on data as specific digital artifacts, shedding light on the process by which data are generated, managed and transformed into actionable and valuable objects for a certain use context (Aaltonen et al., 2021; Aaltonen and Tempini, 2014; Alaimo et al., 2020; Alaimo and Kallinikos, 2020). Data are described as "bearers of facts that express meaning and value" (Aaltonen et al., 2021). Data are initially produced as "sign tokens used to describe, index, represent or stage (perform) reality" (Alaimo et al., 2020). Data are initially produced under particular conditions and can never be considered as completely "raw" (Gitelman, 2013). The representation of reality (or facts) conveyed by data is indeed determined by the specific formats and language used to record data, that is guided by an initial usage context: as indicated by (Aaltonen et al., 2021) "to become data, events yet to be recorded or existing records need to be imagined as data for some purpose". However, because data record facts in a certain standardized way, they become 'portable' across settings and organizations and can be repurposed by 'recontextualizing' data according to new usage contexts (Aaltonen et al., 2021; Alaimo et al., 2020). For example, (Aaltonen et al., 2021; Aaltonen and Tempini, 2014) investigate the case of a telecommunications operator that transformed data (recording of every click, call and message relayed through the network), initially produced to manage the network infrastructure (e.g. allowing optimal allocation of resources, detecting misfunctions or suspicious activity), into data commodities sold to advertisers (transforming initial data tokens in specific metrics related to the advertising audience).

It thus appears that data are always related to a certain usage, that is however made more or less explicit along successive data transformations. In particular, the link with the initial usage context might become quite loose as data become recontextualized for new purposes

(Aaltonen et al., 2021). However, it is also important to recall that it is ultimately this initial usage context that “sets the boundaries” of what can be later derived from data (Aaltonen and Tempini, 2014), e.g. due to the validity domain of the technology employed for data production. This has been further stressed by scholars calling for specific “data stewardship practices”, that would especially keep traces of data transformations all along its circulation among organizations to guarantee the quality of data and avoid potential misinterpretations and misuses (Martin, 2015). Based on these considerations and to further underline the inseparability of data from a certain usage context, we will therefore describe *the action of developing usages of data as a transformation of an initial data-usage pair into new data-usage pairs where both data and usage can be modified compared to the initial use context.*

Although this stream of works has extensively described the complexity of the tasks underlying such a transformation process, several blind spots can be however noted. First, it has mainly considered empirical cases where the new developed usages remain within the boundaries of a specific industry, e.g. telecommunications (Aaltonen et al., 2021) or music industry (Alaimo and Kallinikos, 2020). (Aaltonen et al., 2021) also mention the relevance of such an approach for data considered as very context-specific, such as health data or hard science data, that could be repurposed in various contexts. However, these works do not yet address the question of how to recontextualize data in contexts that are not limited to a certain industry but that would span heterogeneous ecosystems spanning various industries. Second, despite describing recontextualization as an open-ended process, these studies have little addressed the question of how such an effort is managed in a longer-term perspective to ensure a continuous development of new usages. Making progress on these little-studied aspects appear as crucial in fully unleashing the generativity potential of data beyond the existing boundaries of industries. This leads us to formulate the research question investigated in this paper as follows: *how to manage a continuous and repeated transformation of data-usage pairs spanning highly heterogenous ecosystems?*

As underlined by (Aaltonen et al., 2021), repurposing data involves intricate coordination and articulation mechanisms between actors. Interestingly, an important stream of research in innovation management has more specifically investigated a specific class of actors called “innovation intermediaries” involved in facilitating exchange among a variety of actors to support innovation processes. This literature provides us with interesting insights to further describe the types of actions at stake in transforming data-usage pairs, that could indeed be seen as a specific innovation process involving multiple actors.

2) Innovation intermediaries

Innovation intermediaries are characterized as central actors in supporting innovations processes. They have been studied by various research streams, e.g. referred as knowledge brokers (Hargadon, 2002, 1998), innovation brokers (Klerkx and Leeuwis, 2009; Winch and

Courtney, 2007), bridge builders (Bessant and Rush, 1995), boundary organizations (Guston, 2001; O'Mahony and Bechky, 2008). In his seminal paper, (Howells, 2006) builds upon different research streams on technology diffusion, systems of innovation, innovation management and service organizations to define an innovation intermediary as "an organization or body that acts an agent or broker in any aspect of the innovation process between two or more parties". They undertake numerous functions and activities, and can take different organizational forms, such as consultants (Bessant and Rush, 1995; Hargadon and Sutton, 1997), industry associations, chambers of commerce, innovation centers (van Lente et al., 2003), or other government-affiliated organizations (Kivimaa, 2014).

The role of such intermediaries appears particularly crucial in contexts with a high degree of unknown regarding technologies, markets or which actors to involve (Stewart and Hyysalo, 2008). Intermediaries thus act as "boundary-crossing" actors involving a large variety of disciplines, actors, interests, value systems, fields of activity and institutions (Boon et al., 2011). Scholars have highlighted various forms of intermediaries playing an important role in such contexts: intermediaries supporting demand-articulation processes (Boon et al., 2011, 2008), systemic intermediaries accompanied by an ecology of intermediaries supporting the complex and long-term changes involved in transitions to sustainable development (Kivimaa et al., 2019; van Lente et al., 2003), or intermediaries playing the role of "architects of the unknown" by stimulating and driving collective exploration and knowledge creation (Agogué et al., 2017, 2013). Among these different studies, we more specifically build upon the framework proposed by (Stewart and Hyysalo, 2008), synthesizing the activities of intermediaries in three main functions:

- (1) *Facilitating*, i.e. educating, gathering and distributing resources, influencing regulations and setting local rules in order to create "spaces" for others to act.
- (2) *Configuring*, i.e. shaping the technology including both technical aspects but also use-related aspects (e.g. suggesting or stimulating certain usages).
- (3) *Brokering*, i.e. establishing or modifying connections between actors (potentially bringing users and suppliers together but also involving other important actors in the innovation network) .

This framework appears as particularly relevant to us in addressing the question of developing data usages in heterogeneous ecosystems. Indeed, data appear as largely unknown to the various ecosystems that could however benefit from them (e.g. farmers could benefit from yield prediction based on Earth observation data but might not have the interest or competencies in integrating data in their daily activities), thus requiring such "boundary-crossing" activities involving a large variety of expertise fields and actors. Moreover, the framework proposed by (Stewart and Hyysalo, 2008) especially describes cases where intermediation is required to bridge users and developers of a certain technology and has been more specifically developed through empirical investigations in the context of information and communication technologies. Our research question is thus investigated

through the lens of innovation intermediaries and could be precised as follows: *in order to manage a continuous and repeated transformation of data-usage pairs spanning highly heterogenous ecosystems, to what extent specific actions of facilitating, brokering, configuring are required?*

III. Methodology

This research uses a qualitative methodology, relying on multiple case studies (Yin 2009). We indeed investigate the case of organizations that have been developing services based on Earth observation data for various types of actors (industries, public bodies, research communities), for at least several years, in order to study the dynamics of the ecosystems and the related actions carried out by these organizations. The selected case studies are particularly relevant for the research question under study. Indeed EO data, initially produced mainly for scientific goals to monitor the planet and its environment based on several instruments (satellites, in-situ sensors etc), are now available to every economic actor thanks to active 'open data' policies. These data appear to be a promising resource to help various sectors tackle socio-environmental grand challenges they are facing, but seem surprisingly underused in practice.

1) Empirical materials

Three authors of this paper (first, second and fourth) are involved in a large research project, funded by the European Commission under the Horizon 2020 programme. This project, called *e-shape*, brings together a team of 60 experienced partners from academia, industry, institutional entities and user communities to develop 32 pilot applications based on Earth observation data, gathered in seven showcases (food security, health, renewable energy, biodiversity, water resources, disaster resilience and climate). The authors are leading a work package dedicated to the progressive design and experimentation of a co-design approach supporting the different pilots. This setting allows the authors to conduct a multiple case study approach (Yin, 2009) in a unified context. Indeed, a distinctive feature of the portfolio of pilots lies in its variety. Each pilot corresponds to a certain context: it is managed by a focal actor - the pilot leader - that can be of different types (public research institute, private company, etc). This pilot leader interacts with various user groups on the one side and other stakeholders providing specific resources required to build the service on the other side (e.g. data sources, infrastructure, scientific models).

Thanks to our implication in the project, we have access to all the organizations involved in these pilots, as well as the users they interact with and their network of partners. Different forms of empirical materials can be exploited: questionnaires, interviews, observation notes taken during project meetings, and secondary sources of data on the different actors (mainly websites and scientific publications).

2) Data collection and analysis

The context of each pilot was analyzed following the same process:

Step 1 - Secondary sources of data were used to build a first understanding of each pilot (application forms filled-up by each pilot to participate to the project, completed with websites and research publications).

Step 2 - A framework was then used to synthetically represent each pilot as a chain linking data sources, information, usages and associated users (see a example in Annex).

Step 3 - A questionnaire was sent to each pilot to validate this framework representation and ask additional questions on unclear elements.

Step 4 - Answers were used to precise the analysis of each pilot on five main points: (1) overall understanding of the usage ecosystem (overall context, specific regulations, organization of the communities, contact points in these users' communities); (2) users' competencies (familiarity with EO data, ability to integrate the service in their own operations); (3) types of usages expected to be designed; (4) pilot-user relationship (history of the relationship, level of engagement, interaction modalities); (5) ability of the pilot to transform a first prototype in an operational service (upscaling challenges, operationalization resources, additional partners to be involved).

Step 5 - An interview of one hour and a half was carried out with each pilot to further clarify these five points.

Step 6 - Following the interview, we wrote a detailed a report detailing these five and updated the framework representing the pilot. These written documents were reviewed and validated by the pilot.

IV. Results

The outcomes of the analysis process, materialized in the completed framework and a report for each pilot, are simplified and presented in a table (see Annex) focusing on the following aspects: overall pilot's rationale (giving the general context of the pilot), type of focal actor supporting the pilot development, targeted user groups, expected usage contexts (i.e. the type of action that is expected to be taken by user groups thanks to the provided service), the type of generic information on which these various usages are based, the key data sources used to derive such information.

Based on this analysis, we can first validate the specific intermediary role played by the pilots in e-shape. Indeed, it clearly appears that they are involved in making the link between data producers and data users, transforming initial data-usage pairs (associated with contexts of data production) into new data-usage pairs (associated with the user groups' contexts). Moreover, the specificities of such intermediary actors can be further described according to their brokering, configuring and facilitating activities.

Brokering

The cases reveal an intriguing type of brokering, that does not consist in creating direct connections between data producers and data users, contrary to what is often encountered in open data initiatives (Zuiderwijk et al., 2014, 2012). This results from the high level of heterogeneity between data producers and data users and more specifically the impossibility of each side to directly respond to potential demands from the other side. To take the examples of pilots involved in providing farmers with specific EO-based services, satellite builders could not directly respond to farmers expectations making technical modifications of satellites in a way that would be satisfying for farmers, as it would involve large costs and development time (e.g. at least 10 years to launch a new satellite). In this context, the pilots serve as a kind of buffer zone between data users and data producers, managing the potential divergence in terms of dynamics and performance logics between these actors. It is also important to notice that this buffer role does not involve a complete separation between data users and producers. Indeed, when interacting with data users, the pilots represent data producers as it requires leveraging and integrating their resources and expertise. And vice versa when interacting with data producers, the pilots also represent data users by sharing the knowledge they have built on data usage contexts.

Configuring

According to the definition proposed in (Stewart and Hyysalo, 2008), configuring consists in shaping the technology including both technical aspects but also use-related aspects (e.g. suggesting or stimulating certain usages). These authors also indicate that only minor adjustments of the technology itself are involved. In the context of developing usages from data, these adjustments consist in transforming initial data-usage pairs in new ones and can take specific forms that can be more or less important depending on the initial and targeted usages. It is especially important to notice that the different data-usage pairs built by each pilot (indicated in the table by the variety of expected usage contexts) are all built on a common core, a certain type of information derived on the various data sources and compatible with various usages (see “generic information” column in the table). This suggests that the efforts of the pilots do not consist in building a new data-usage pair from scratch for each new usage but rather in building this specific kind of generic information. The form of this information is not given and fixed once and for all but rather results from operations both related to the initial context of use and the targeted usage contexts. Operations related to the initial use context consist in considering what parts of the context need to be kept, what other parts need to be hidden, involving the development of specific scientific models and documentation on the processing chain. Operations related to a targeted context of use consist in considering the parts of the context to be integrated in the generic information that should ensure that a certain usage could be developed within this specific context, but in a way that could be potentially compatible with other usage contexts.

Facilitating

As defined by (Stewart and Hyysalo, 2008), *facilitating* involves creating spaces for others to act, through educating, gathering and distributing resources, influencing regulations and setting local rules. The analysis of the pilots reveal two forms of facilitating activities, coined ‘non-specific’ and ‘specific’ facilitating activities. The former category corresponds to facilitating actions that are not specifically adapted to a certain type of users, for example help desk dedicated to answer users’ questions, or training sessions on the basics of Earth observation. This ‘non-specific’ form of facilitating is similar to what was described by (Stewart and Hyysalo, 2008) in the case of cybercafes that provided users with training and advice related to the use of computer and software. However, in the case of EO data, this first type of facilitating is also complemented with a ‘specific’ form of facilitating that needs to adapt to the specificities of the users’ contexts. Indeed the nature of the capacities and knowledge to be developed and shared might not be known in advance by the pilots themselves. Therefore, all pilots are involved in specific co-design activities in order to identify what kinds of spaces would be required by the actors to act on their own, and what kinds of support the pilots should bring to effectively create such spaces. This can require various efforts from the pilots such as building customized supporting tools or advice, but also pushing specific norms to make the use of EO data recognized by a certain community (e.g. defining what is a ‘good’ prediction of solar radiation, or promoting the potential of EO data compared to other data sources that are more commonly used).

V. Discussion and conclusion

The specificities of the brokering, configuring and facilitating actions carried out by the pilots suggest that they can be considered as a specific form of intermediaries that cannot be fully described through existing figures reported in literature. Similar figures can be also found in other research works, although not directly referred as “innovation intermediaries”. (Kokshagina et al., 2016) for example suggest a new managerial role – a ‘cross-application manager’ – to support the development of generic technologies. Data generativity builders might also be compared to ‘platform leaders’ (Gawer, 2014). These platforms would rather correspond to innovation platforms rather than transactional ones.

This paper offers several contributions. First, our study reveals the role of a specific economic actor, that we could coin ‘data generativity builder’, that appears as crucial in continuously expanding data usages for a large variety of actors. This question is not limited to the EO context. Indeed, unleashing the generative potential of data has been specifically acknowledged as a promising resource in facing contemporary grand environmental and societal challenges such as poverty, illness, conflict, migration, corruption, natural disasters, climate change, and pollution (Chandy et al., 2017; George et al., 2020). These authors underline the importance of stimulating data use and reuse by various actors spanning heterogeneous sectors that could not necessarily be foreseen by the data producer, as in the

EO context. Our study suggests that such process could be better supported in a long-term perspective by strengthening a network of intermediary actors involved in building data generativity, although the organizational forms of such intermediaries in these different contexts would need further investigation.

This paper also contributes to information systems literature by investigating the question of ‘recontextualizing’ data in a repeated manner and in heterogeneous ecosystems. Our study shows that performing repeated and multiple transformations of data-usage pairs do not only involve actions related to recontextualizing data (i.e. adapting data to a new usage context), but also specific actions to build a generic information core common to different data-usage pairs.

Several limitations are worth being noticed. Our analysis is based on the analysis of actors that are currently developing usages to EO data and thus does not characterize the evolution of these actors’ activities over time. Moreover, we do not specifically discuss the different organizational configurations of this ‘data generativity builder’ and their potential implications for the long-term success of the approach. Digging into longitudinal case studies would be interesting to further analyze these different aspects.

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Annex (to be simplified)

Pilot's rationale	Focal actor (pilot leader)	Targeted user groups	Expected usage contexts	Generic information	Key data sources
Supporting global agricultural monitoring	Independent research institute	GEOGLAM (Group on Earth Observations Global Agricultural Monitoring Initiative): international organization gathering national, regional and global agricultural organizations and administrations	Monitoring crop calendar information, especially for two regions: Greece and Ethiopia	Crop calendars (specific field interventions such as harvest, planting or ploughing)	Satellite data (Copernicus) Satellite data from Proba V (VITO) In-situ data when available (use of a specific data sharing platform) Soil data base spectral library (iBEC) Citizen-sourced data (IIASA) Standard and Open Meteo data and services (e.g. precipitation, forecasts)
Supporting farmers for CAP (Common Agricultural Policy) compliance and farm performance	Public research institute	Agri-cooperatives Farmers Insurance companies Paying agencies	- Monitoring crop information expected yields coupled with meteorological risks - System for scientific purposes	Crop growth (yield assessment and forecast, damage assessments)	Satellite data (Copernicus) Soil data base spectral library (iBEC) Citizen-sourced data (IIASA) Standard and Open Meteo data and services (e.g. precipitation, forecasts) In-situ telemetric stations (provided by an IT SME)
Supporting farmers with crop insurance services in Ethiopia	Public research institute	Digital finance and payment services' provider Insurance Companies Micro-Finance Institutions Various key-government agencies	Monitoring system for droughts: based on the processing of an enriched NDVI, considering zone and season specificities.	Crop insurance product covering impacts by droughts	Vegetation index from various satellite sources (SPOT-VGT & PROBA-V, Sentinel-3, Copernicus)
Supporting agriculture activities at farm level	Independent research institute	Agro-consultants Policy Makers Agricultural cooperatives Agro-industries Farmers	Monitoring system of crops at field level Towards decision/design support system	Crop calendars at parcel level (specific field interventions such as harvest, planting or ploughing)	Satellite data (Copernicus and VITO) In-situ data when available (use of a specific data sharing platform) Soil data base spectral library (iBEC) Citizen-sourced data (IIASA) Standard and Open Meteo data and services (e.g. precipitation, forecasts)
Providing customers with field and/or regional level information rather than simply in-	Riscognition is a private company specialized in the processing of EO imagery Elmibit is a	Riscognition: agriculture software developers Elmibit: farmers	- A specific service provision linking in-situ data with EO information to create time series and improve forecasting - A monitoring system with	Soil and crop moisture (at 10m resolution) Vegetation stress (at 10m resolution)	Satellite data Sentinel 1 & 2 and other Copernicus services (Copernicus) In-situ data: farmers in-situ data

situ in order to Increase the understanding of moisture across the farm	smart agriculture software company		regularly updated information about the state of farmers' crops and fields - Decision support system		
Providing national decision makers with high quality national scale information based on high resolution data	Public space research institute	Governmental entities Academics Research institutes Commercial entities	3 information systems: - Country level SDG indicators information + report form - Assessment of regional crop state, crop emergency and land use + Report form - Information provision of the land use, crop area, crop state, land degradation and SDG Technologies and data provision: - Data and expertise for educational purpose - Land productivity and SDG assessment	Information on agricultural land and crops: - SDG 15.3.1 - SDG 2.4.1 - Land cover maps - Crop maps - Agriculture productivity - Agriculture emergency - etc.	Copernicus data: Landsat-8 and Sentinel 1 & 2 Users' data: - In-situ and weather data - Crop data, crop calendars or other geospatial vector or raster layers - vector files with in-situ land cover\crop types labels and in-situ LAI\NDVI or other crop state date for validation
Surveilling mercury pollution	Public research institute	Health communities Conference of Parties Local and regional authorities	Decision support system for policy makers that aim at assessing the efficiency of the measures taken by policy makers to reduce mercury emissions	Mercury deposition in the environment	Satellite data (Copernicus), Multispectral high-resolution images Specific data base gathering mercury measurements
Surveilling persistent organic pollutants	Public research institute	Policy makers Conference of Parties (COP) Scientific communities	Monitoring system of POPs for policy makers: - Data collection on POPs levels in different core media; - Editing and visualization tools	Persistent Organic Pollutant concentration in core media (air, human tissues, water)	Sampling networks of polutants in air, human tissues and water

Improving information on air quality and related health issues, for use in public health assessment and urban planning.	Public research institute	International organizations, National authorities Cities and municipalities Insurance companies Real estate companies	Monitoring system for air quality, enriched with different layers of information (air quality, health, socio-economic, etc.), and specific visualization tools.	Air quality at global, city and municipality scales at different time horizons	<ul style="list-style-type: none"> - Remote sensing data from various sources - In-situ data - Open AQ Datasets - Low cost sensor networks - IIASA
Nowcasting and short-term forecasting of solar energy	Public research institute	Ministries of Electricity and Renewable Energy Power generation operators Power distribution and transmission operators	Specific service provision: <ul style="list-style-type: none"> - Historical solar data and aerosol load data for specific locations. - 1-2-day solar forecasting window 	<ul style="list-style-type: none"> - Solar surface irradiance - Maps, databases and on the fly requests 	<ul style="list-style-type: none"> - Copernicus data: CAMS, Sentinel - AEROCOM database - Meteosat (EUMETSAT) - In-situ data: ground-based aerosol optical properties and others Other data: <ul style="list-style-type: none"> - Pre-calculated radiative transfer model outputs
Encouraging high photovoltaics penetration in urban areas	Public research institute & national spatial agency	Energy providers Citizens Collectivities & urban planners	Monitoring system of the PV production variability at urban scale (nowcasting, forecasting) <ul style="list-style-type: none"> - Modelling tool for urban energy system, - Specific service provision (scientific advisory or joint inquiry) 	<ul style="list-style-type: none"> - Variability assessment and forecast of SSI - Characterisation of existing PV and potential roofzones - Shaded surface irradiance - SSI variability - PV yield simulation - Urban classification - Meteo information 	<ul style="list-style-type: none"> - Copernicus data: CAMS and Sentinels 1 & 2 - Other satellite data sources: airborne, building cadastral 2D plans, etc. - Other data sources: in-situ measurements and yield simulation or electric loads
Providing wind resource assessment tools for the offshore wind industry	Public research institute	Offshore wind farm developers Offshore wind farm operators Consultants Research, academia, educators	Type of system still to be discussed with users. Web-portal for on-demand information provision, and showcasing DTU's expertise: <ul style="list-style-type: none"> - Portal giving access to maps, explanations on the methodology, processing chains 	An enriched & unified wind product <ul style="list-style-type: none"> - Mean wind at - Wind power density - Wind direction distributions - Weibull parameters 	<ul style="list-style-type: none"> - Copernicus data: Sentinel 1, ENVISAT, CMEMS (EO and in-situ data) - Other data sources: Global Forecasting System model data (NOAA) and Meso-scale atmospheric model outputs (DTU Wind Energy)
Providing sustainable EO based data sets for wind energy planning	Earth Observation knowledge hub	Wind turbine manufacturers Consultancy companies Research institutes	Data package: map layers for wind resource assessment and siting.	<ul style="list-style-type: none"> - Map layers - New parameters (tree height and LAI) 	<ul style="list-style-type: none"> - Copernicus data: Sentinel 1 & 2 - Earth Observing System (EOS, NASA): ICESat-2 observations - Turbine and wind information (users' data)

Monitoring and modelling the trends and states of ecological ecosystems through the integration of remote sensing maps and in-situ data	Research institutes (public/private)	Technical staff and managers of European Protected Areas (PAs)	monitoring system of the ecosystem state and changes based on EO data.	Consistent information for indicators and variables to monitor the ecosystem state and changes Geographical scale: European scale	<ul style="list-style-type: none"> - Gridded datasets (e.g., EOBS) - Copernicus Climate Change Services (C3S) - Remote sensing (RS) data (CMEMS and Sentinel, Copernicus) - Earth Observing System (EOS, NASA): MODIS/Aqua - In-situ measurements: eLTER network
Building an extended common registry of observation and experimentation facilities of ecosystems as the basis for the integration of available information	Research institutes (public/private)	Research communities Technical and scientific staff of project groups European and national conservation agencies	Monitoring system Site monitoring, providing information that leads to be more and better informed in order to take actions;	Biodiversity and ecosystem data available for a specified area of interest	<ul style="list-style-type: none"> - Global, documentation and sharing of site information and related datasets - European, metadata catalogue providing information on in-situ data provided by the eLTER RI and LTER Europe network - EO based EBV from GEOBON portal (Copernicus)
Improving the services and functionality of the Essential Biodiversity Variables data portal, providing harmonized sets of variables for biodiversity observation and conservation.	Research institutes (public/private)	Research communities Monitoring agencies that inform ministries	Biodiversity monitoring system and assessing targets Numerous tasks: - Production and delivery of data, set up indicators through a portal + reports on different topics - Set connexion between EO data production and in-situ data	Essential Biodiversity Variables (EBV) - Different scales: three levels of sites (SG1 = core sites, SG2 = integration sites, SG3 = coverage sites) + national scale	<ul style="list-style-type: none"> Derived EO data products EO products from ECOPotential project (Copernicus) In-situ measurements (eLTER network)
Providing historical and near-real time information for a number of hydrological variables	Public meteorological and hydrological institute	Geological institutes Water and marine authorities Hydropower companies Emergency response Management centers Researchers	Monitoring system based on the improved hydrological information at specific locations at near-real time/forecasts	Long historical records + medium range & seasonal forecasts of different hydro-climatic variables over Sweden	<ul style="list-style-type: none"> EO-based data: <ul style="list-style-type: none"> - Copernicus Global Land Monitoring, ESA GlobSnow... - MODIS - Sentinel 3 (Copernicus) - Flood extent mapping Meteorological forcing data

Estimating flood hazard at a large-scale	Public meteorological and hydrological institute	Research and meteorological institutes R&D Companies Modelling flood risk authorities	Mainly monitoring system of water bodies over Europe: Decision/scenario-based design support system	- Water bodies and floodwater records - Surface water volumes, exceedance probabilities, return period of flood, etc.	Copernicus data: - Sentinel-1 - ENVISAT image collections (2002 - 2018)
Providing a near-real time visibility score for specific diving locations	Public laboratory	Diving centers, commercial divers	Weather report/monitoring service/ forecasting	Visibility score at near real time	CMEMS (Copernicus)
Predicting the landing areas and severity of the sargassum algae season	Private company	Local authorities Research community Tourism companies	- Monitoring system integrated in Meteo France's own workflow - Specific service provision: sargassum detection index integrated in a specific tool for operational use - With CERMES: a design support system could be considered in addition to provision of CLS algorithm's outputs	Sargassum identification and characterization Prediction several months in advance of landing areas and severity of Sargassum Time series of NFAI (Normalized Floating Algae Index)	- Earth Observing System (EOS, NASA): MODIS Aqua - Copernicus: Sentinel 1, 2 & 3 and CMEMS - Other sat-based information: ocean surface current and wind data (NOAA) - Unprecised data sources: bathymetry and coastlines
Improving monitoring and regulation of fishing activities in the Northeast Atlantic	Private company	Fishermen associations NGOs International organizations scientific communities Regional and national authorities	Monitoring system of fishing activities through a Geo-Portal	Characterization of fishing activities with visualization tools Pressure indicators Further development of CFP Data collection framework and MSFD indicators	DGRM's (user) data: - Vessel monitoring system - Fishing vessels VMS data - Vessels technical characteristics - Fishing e-logbooks data - Fishing e-logbooks data - Landing declarations - Fishing fleet landing declarations Other data: - in-situ, satellite and model EO data streams (CMEMS (Copernicus), etc.) - Automatic Identification System data - Bathymetry and sediment chart

Providing WFD ecological status products of phytoplankt on biomass for management of selected water bodies	Research institute spin-off	Research center Water authorities EU level public water bodies National regulators (maybe) Dredging companies	Monitoring of phytoplankton biomass for WFD reporting based on EO data + potentially other systems to be explored (decision support system or scenario design support)	EO data to improve water quality measurements: - Better quality/accuracy and continuous spatial data Cloud-free images - Measure the concentration of Chlorophyll-a	- Sentinel 3 A & B (Copernicus) - Sentinel 2 A & B (Copernicus) - EEA, LIMNADES, GEOSS public databases
Providing aquafarmer with information about mussels in weekly bulletin, with indicators in order to prevent the impact of extreme events due to climate change	Private company (solution provider)	Aquaculture commercial companies	Rheticus® Aquaculture provides farmers with smart information in the form of analytics, trends, and alerts to boost productivity or promptly identify critical issues (weekly report)	Information to improve water quality measurements - the weekly value and estimation of growth and growth trends - 14-day forecast of mussel growth, - comparative analysis of growth rate - temperature - level of plankton	CMEMS (Copernicus): - Sentinel 2 & 3 Users' in-situ data: - Geographic coordinates of the production site or a georeferenced vector file - Seeding date; - Seed dimension; - Sorting and socking dates and sizes.
Improving monitoring of volcanic eruptions	Public research institute	Special units in meteorological institutes Air traffic managers Civil protection authorities Local authorities Policy makers	- Monitoring system of 4D volcanic plume distribution - Information provision	- 4D distribution of volcanic plume over Europe, - Alert and characterization of the source - Forecast of Ash dispersion	Copernicus data: - Ash plume tracking (MODIS, SLSTR –Sentinel 3) Other data: - EPOS, LIDAR and in-situ observation data - NASA/NOAA data: SO2 tracking and aerosol index ACTRIS data: Aerosol optical property profiles and Ash concentration & vertical mask
Developing a tool for fire and risk assessment and supervision scenarios	Public research institute (officially linked to the national Civil Protection Authority)	National and regional civil protection authorities Hydro-Meteorological Agencies	- Monitoring & decision support system providing scenarios for possible risks of fire and flood - Visualization tools - Specific service provision (support to improve hydro-meteorological chain)	- Enhanced meteorological information on limited area - Enhanced information on high-impact weather events - Impact assessment information - Updated Land Use Land Cover (LULC) and LULC Change Detection Maps	Copernicus data: - Sentinel-1 - Sentinel-2 L1C - Sentinel-3 L2 Personal Weather Stations Statistics on: - Number of people affected by a given natural hazard - Economic impacts/costs by a given natural hazard

Assessing geohazard vulnerability of cities and critical infrastructures	Public institute & private company	Urban managers and civil protection authorities Energy and infrastructure companies Policy makers	<ul style="list-style-type: none"> - On-demand service provision: INSAR data - Decision support system customized to users' competencies and daily operations and alarms on status of the network with visualization tool 	<ul style="list-style-type: none"> - Active deformation Areas maps - Landslide and Subsidence activity Maps - Vulnerability Elements activity maps - Change detection - Pipeline Alert 	<ul style="list-style-type: none"> - Sentinel 1 (Copernicus), Cosmo-SkyMed and TerraSAR-X - In situ ground deformation data derived from Global Navigation Satellite System observations - Urban geohazard maps: - Specific data from users
Providing information on geohazard vulnerability of agriculture	Public research institute	Insurance company Farming cooperatives	<ul style="list-style-type: none"> - Historical information on the phenomena occurring in the area - Risk and damage assessment in real time - Monitoring system providing information to insurers - Early warning system - forecasting based on meteorological predictions. - Early warning system of disasters - Monitoring system for cotton crops' phenological state 	<p>Hazard information:</p> <ul style="list-style-type: none"> - Disaster assessment and forecast - Crop type and natural ecosystems mapping <p>Coverage: regional level</p>	<ul style="list-style-type: none"> - Copernicus data: Sentinel 1, 2 & 3 raw data - EO derived parameters/indices - Partner data: in-situ datasets - Standard and Open Meteo data and services - User data: historical data
Providing territorial and ocean carbon and greenhouse gas fluxes information in order to support the Global Carbon Project	Public research institute	Global Carbon Project GHG community SOCAT community	Provision of information and models. Different components to be differentiated (different maturity levels): Atmospheric component, terrestrial component and ocean component	Improved info on terrestrial & ocean GHG fluxes: <ul style="list-style-type: none"> - Land carbon fluxes - ocean product that will reduce the uncertainty in ocean carbon sink estimates - Quality indices 	<ul style="list-style-type: none"> - OCO-2 (EOS), Sentinel 5P TROPOMI (Copernicus) - ICOS (ETC & OTC), MODIS LST/NDVI/LAI/FPAR, Sentinel 3 (Copernicus), ECMWF - Statistics and historical data: ERA5 - ENVISAT SST (Copernicus), ERS2 wave/wind, SMOS,... - Global in situ EOV Inorganic Carbon surface ocean data

<p>Providing information to municipalities on heat waves, heavy precipitations and extreme weather events</p>	<p>Public meteorological institute</p>	<p>Cities and municipalities Consultancy company for urban climatology and wind research</p>	<ul style="list-style-type: none"> - Monitoring system for extreme weather events - Warning system for extreme weather events 6-week ahead - Scenario design support system - Monitoring system for extreme weather events - Monitoring system with dynamic visualization data - Scenario design support system 	<p>Weather and climate seasonal forecast:</p> <ul style="list-style-type: none"> - Urban Heat Index - Drought - Precipitation 	<p>Copernicus C3S Seasonal forecast</p> <p>HARMONIE model (NWP & Météo-France), AROME model (Météo-France), INCA model forecasts</p> <p>In situ-observations</p>
<p>Providing seasonal forecasting of forest harvest conditions to support forest industry organisations and companies</p>	<p>Public meteorological institute</p>	<p>Private companies in forest management support R&D company</p>	<p>Combination of modules going from monitoring to more decision-support oriented module</p> <p>Smart harvesting service: evaluation of the carbon impact of forest management practices.</p>	<ul style="list-style-type: none"> - Forecast frozen soil depth and soil moisture - Improved map resolution - Forest management options - Estimate carbon emission impacts of these different harvesting scenarios - Geographical coverage: Northern European boreal zone forest areas 	<p>C3S data (Copernicus):</p> <ul style="list-style-type: none"> - Copernicus C3S Seasonal forecast ensemble - C3S Climate data Store - Soil Temperature and soil moisture <p>Other data:</p> <ul style="list-style-type: none"> - 5 forest classes laser scanning analysis (Arbonaut) - Forest parcels data - In-situ data
<p>Supporting hydropower companies by better predicting hydrological conditions</p>	<p>Public meteorological institute</p>	<p>Energy companies</p>	<p>Public monitoring system about snow distribution before it starts melting, assessing when the peak flow will occur and how much water it will represent to shape the hydrograph</p> <p>On a longer-term: a scenario-based design support system to explore ways of managing dams</p>	<ul style="list-style-type: none"> - Snow information: Snow Water Equivalent, Snow Depth, Snowmelt rate - Surface runoff, soil column inter and base flow - River discharge and reservoir inflow - Reduced hydrological model uncertainties 	<p>C3S data (Copernicus):</p> <ul style="list-style-type: none"> - Seasonal forecast ensemble - C3S Climate Store <p>Other Copernicus data: Sentinel 1-2-3 (OLCI and SLSTR data).</p> <p>Other data</p> <ul style="list-style-type: none"> - HydroSAF (Sensors + weather station observations) - Snow state verification with Webcam snow monitoring network

<p>Helping transportation and tourism sectors to better prepare for seasonal changes</p>	<p>Public meteorological institute & public research institute</p>	<p>Tyres companies Tourism stakeholders</p>	<p>Optimizing/designing retail operation and logistics</p> <p>EO monitoring system and visualization tools and warning system</p>	<ul style="list-style-type: none"> - Probabilistic estimations of onset/offset dates of the winter driving conditions for Finland - Probabilistic estimations of climate-tourism indicators for Greece 	<p>Copernicus data:</p> <ul style="list-style-type: none"> - European seasonal forecasts from C3S Climate data Store - Sub-seasonal model data from ECMWF - ERA5 re-analysis <p>In-situ data</p> <p>Users data:</p> <ul style="list-style-type: none"> - Auxiliary data from tire companies/tourism on the previous seasonal demands
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