Space Applications for Agricultural Purposes: Relevant Legal Framework

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It is a well-established fact that space technologies, particularly satellite remote sensing and positioning sensors and services, can be used to improve agricultural processes and practices, and ultimately increase productivity and profitability of the activities. Many entities worldwide, including the United Nations through its Committee on Peaceful Uses of Outer Space, emphasise importance and promote use of space technologies within the agricultural sector. The paper highlights various agricultural activities and areas where space technologies can and are being used, including but not limited to precision farming, phytopatology and agricultural risk management. Based on this overview, it explores the legal framework relevant for development and use of space applications for various agricultural purposes. It focuses on two main aspects in this regard: regulatory framework applicable to the actual development and use of space applications; analysis of how use of space applications and technologies can aid implementation of legal obligations stemming e.g. from the International Biodiversity Convention, International Plant Protection Convention, or the Rotterdam Convention regarding international trade in pesticides, as well as recommendations from international bodies regarding sustainable ways of agricultural production. To conclude, the paper summarises the most important legal and regulatory aspects relevant to the development and use of space applications for agricultural purposes.

I. Importance of Space applications for agricultural purposes

One of the effects of globalisation is that economies become more intertwined and management of many processes cannot be restricted to political boundaries of individual countries. States have to manage together global concerns and resources like food, water, energy and natural

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environment. For example, the effects of agricultural underproduction in one country or a region of the world might be felt by countries that import produce in question from there. Space technologies and their applications can help resolve issues faced by the globalised community as they are able to provide a common data resource and global-view infrastructure useful for decision-making purposes.[1]

Applications based on satellite Earth observation (EO) data alone or couple with satellite technologies like navigation and positioning can be extensively used in the agricultural sector. EO high resolution data can aid the detection of inadequate irrigation and soil erosion. EO data products and services can significantly contribute to the efficiency of modern agricultural practice, and provide consistent and broad geographic coverage that is of high importance to the large companies in today's markets[2], as well as countries in need to address challenges of globalisation and meet sustainable development goals. EO data and information products can improve revenues of farmers, for example by providing better guidance regarding optimal use of pesticides, by timely delivered information about possible or actual pest infestations, plant diseases, as well as by identification of poor farming practices.

Some of the terrestrial variables relevant for both agriculture and climate change monitoring that EO satellites can well detect and relevant for agricultural purposes include snow cover, land cover (including vegetation type), above-ground biomass, soil carbon, soil moisture.[3] Land cover information is important because the land is where most of the Earth's population lives. It meets the major part of societies' food, fuel, freshwater and fiber requirements and shapes planet's climate system.[4] An additional advantage of satellite technologies is their ability to provide timely, synoptic, cost efficient and repetitive information regarding the observed phenomena.[5]

Satellite EO data and information products of particular importance for farmers of all sizes include mixed crop conditions, rain fed-system

1 Pratistha Kansakar, Faisal Hossain. A review of applications of satellite earth observation data for global societal benefit and stewardship of planet earth. *Space Policy* 36 (2016) 46-54, at p. 48.

2 Laurent Probst *et al*, Space tech and services Applications related to Earth Observation Business Innovation Observatory. Study for DG Internal Market, Industry, Entrepreneurship and SMEs. Contract No 190/PP/ENT/CIP/12/C/N03C01 (February 2016), at pp.6-7. Online https://ec.europa.eu/docsroom/documents/16591/attachments/1/translations/en/renditions/native.

3 *Space Innovation*, OECD Report (2016) at p. 96.

4 Alan S. Belward, Jon O. Skøien. Who Launched What, When and Why; Trends in Global Land-cover Observation Capacity from Civilian Earth Observation Satellites. *ISPRS Journal of Photogrammetry and Remote Sensing* 103 (2015) 115–128, at p.128.

5 Clement Atzberger, Advances in Remote Sensing of Agriculture: Context Description, Existing Operational Monitoring Systems and Major Information Needs. *Remote Sens*. 5 (2013) 949-981, at p.957.

experiencing temperature stress and land degradation. They can also be used to assess the two core components of crop production: yield and acreage, as well as to detect crop phenological information, stress situations and disturbances.[6]

Going beyond agricultural production practices, satellite EO data analysed together and integrated with information regarding local farming knowledge and traditional production systems, can aid elaboration of country specific technologies and modelling frameworks for agricultural purposes on macro-levels. This task is however hardly achievable without developing integrated information platforms that that enable data integration and other data value-adding activities that have to be conducted together with diverse stakeholders.[7]

Recognition of the value of satellite EO data and information, as well as of other relevant space technologies is in the various state-run national, regional to global operational agricultural monitoring systems providing critical agricultural information at a range of scales, including but limited to:

- the USDA (FAS) GLAM system;
- the USAID Famine Early Warning System (FEWS-NET);
- the UN Food and Agriculture Organization (FAO) Global Information and Early Warning System (GIEWS);
- European Commission's Joint Research Centre Monitoring Agricultural ResourceS (MARS) action with two main tasks: agricultural production estimates in EU Member States (Agri4Cast), and food security assessments for food insecure countries (FoodSec);
- the European Union Global Monitoring of Food Security (GMFS) program;
- the Crop Watch Program at the Institute of Remote Sensing Applications (IRSA) of the Chinese Academy of Sciences (CAS).[8]

The challenge to successful use of space technologies lies in their reliance on various other technologies and infrastructures, such as data gathering and management systems, geographic information systems (GIS), global positioning systems (GPS), microelectronics, wireless sensor networks

6 Clement Atzberger, Advances in Remote Sensing of Agriculture: Context Description, Existing Operational Monitoring Systems and Major Information Needs. *Remote Sens*. 5 (2013, 949-981, at p.957.

7 Pratistha Kansakar, Faisal Hossain. A review of applications of satellite earth observation data for global societal benefit and stewardship of planet earth. *Space Policy* 36 (2016) 46-54, at p. 50.

8 Clement Atzberger, Advances in Remote Sensing of Agriculture: Context Description, Existing Operational Monitoring Systems and Major Information Needs. *Remote Sens*. 5 (2013) 949-981, at p.957.

(WSNs), and radio frequency identification (RFID) technologies.[9] Data and information from satellites need to be integrated with data from other sources, including, for agricultural purposes, data generated by the farmers and other stakeholders themselves. Their production therefore requires a collaborative approach involving space and applicational (agricultural) sector.[10] Only such integrational approach can result in delivering meaningful tailored solutions on both micro- and macro-levels and producing global solutions encompassing the entire production cycle.[11]

This paper, for the purpose of providing a comparative analysis of application of regulatory regime to activities that may use the same space applications, but use them for different purposes, focuses on three axes – activities relevant to agricultural production and agriculture generally:

- compliance with regulatory requirements with regard to farming practices,
- agricultural risk management: food security and sustainable development;
- agricultural production activities (farming as such).

The specificities and needs of each of the axes are described, followed by an analysis of relevant regulatory framework for production, delivery and circulation of relevant space data and information products and services. The analysis is broken down into several elements inherent to production of integrated space applications: EO; GPS; GIS, data fusion, crowdsourcing, as well as technological control, human safety, civil liability and privacy. It then goes back to the three axes of focus in order to highlight how the relevant general legal framework is modified in order to serve the purpose of achieving successful implementation of each of them, and what the hurdles are.

In conclusion, the paper summarises the most important legal and regulatory aspects relevant to the development and use of integrated space applications for agricultural purposes.

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9 Michail Kritikos, Precision Agriculture in Europe: Legal, Social and Ethical Considerations. European Parliament Study (November 21017), at p.4. Online http://www.europarl.europa.eu/thinktank/en/document.html?reference=EPRS_STU(2017)603207.

10 Teodora Secara, Jean Bruston. Current barriers and factors of success in the diffusion of satellite services in Europe. *Space Policy* 25 (2009) 209-217, at p.210.

11 Résumé des points clés "L'Agriculture: Prochaine Frontiere pour la Politique Spatiale Europeene?" (Mardi 10 juillet 2018, Paris), at pp.4-6. Online https://eurospace.org/wp-content/uploads/2018/07/conference-espace-et-agriculture-10-juillet_vf.pdf.

II. The three axes of Agricultural activities

II.I Compliance with regulatory requirements regarding farming

Monitoring systems inform policy makers and stakeholders about the state of the agricultural sector and the reasons why the current situation exists. In addition, relevant information is also critical for producing impact assessments. Sustainable use of these elements can enable enforcement of measures regarding risk reduction and production of optimised statistical analyses enabling a timely and accurate agricultural statistical reporting at various levels.[12]

The use of integrated space application within the axes of compliance with regulatory requirements regarding farming extends to monitoring and enforcement of existing regulation, as well as providing evidential basis in cases of legal actions resulting from non-compliance. Specifically, space technologies aid monitoring crop residues for conservation program compliance, as well as provide the basis for farmers' decisions regarding regulation compliance.

Regular monitoring through sensor networks, including EO satellites is indispensable for collecting evidence and data that is required by various agricultural regulatory sources, in particular those providing framework for managing aid to farmers and for promoting agricultural practices beneficial for the climate and environment. In the European Union, for example, the so-called Common Agricultural Policy (CAP) requirements[13] led to establishment in each Member State of Integrated Administration and Control System (IACS),[14] including an identification system for agricultural parcels, the Land Parcel Identification System (LPIS), as its spatial component and the main instrument for the allocating direct payments to the farmers once the land and area eligible for payments have been identified and

12 Clement Atzberger, Advances in Remote Sensing of Agriculture: Context Description, Existing Operational Monitoring Systems and Major Information Needs. *Remote Sens*. 5 (2013) 949-981, at p. 956.

13 The most important sources of the CAP regulatory framework include Regulation (EU) No 1307/2013 of 17 December 2013 establishing rules for direct payments to farmers under support schemes within the framework of the common agricultural policy. *OJ L* 347, 20.12.2013, p. 608–670; Regulation (EU) No 1308/2013 of 17 December 2013 establishing a common organisation of the markets in agricultural products. *OJ L* 347, 20.12.2013, p. 671–854; Regulation (EU) No 1305/2013 of 17 December 2013 on support for rural development by the European Agricultural Fund for Rural Development (EAFRD). *OJ L* 347, 20.12.2013, p. 487–548; Regulation (EU) No 1306/2013 of 17 December 2013 on the financing, management and monitoring of the common agricultural. *OJ L* 347, 20.12.2013, p. 549–607.

14 Integrated Administration and Control System, online https://ec.europa.eu/agriculture/direct-support/iacs_en.

quantified.[15] The use of computerised geographical information system techniques for the identification system for agricultural parcels is a legal obligation under the EU regulatory framework. IACS enables localisation, identification and quantification of agricultural land eligible for EU support via very detailed geospatial data, and has become the most important system for the management and control of payments to farmers made under CAP.[16]

II.II Agricultural risk management, food security and sustainable development

The globalised world needs to address well recognised vulnerabilities and risks associated with agricultural production, the most important of which relevant to the subject of this paper are food security (and the issue of world hunger) and sustainability of agricultural production. The four constitutive elements of food security are food availability, food access, utilisation and stability.[17] The right to food was already recognised in the Universal Declaration on Human Rights in 1948,[18] and more recently elaborated upon in the 1996 Declaration on World Food Security[19] that formally adopted the right to adequate food. Unfortunately, statistics provided by the UN Food and Agriculture Organization (FAO) state the world hunger has been increasing in the last three years with respect to previous years' improvement, and there were 16 million more chronically undernourished people in 2017 than 2016.[20]

The Sustainable Development Goals (SDGs) were developed by the United Nations General Assembly and included into UN Resolution Transforming our World: the 2030 Agenda for Sustainable Development.[21] Promotion of sustainable agriculture is set as Goal 2 "Zero Hunger" that also includes food security. The concept of sustainable agriculture includes efforts to make agricultural systems more productive and less wasteful, with agricultural

15 LPIS and agricultural monitoring, European Commision, online https://ec.europa.eu/jrc/en/research-topic/agricultural-monitoring.
16 Michail Kritikos, Precision Agriculture in Europe: Legal, Social and Ethical Considerations. European Parliament Study (November 21017), at p. 8.
17 Food Security. FAO Policy Brief (June 2006), Issue 2, online http://www.fao.org/fileadmin/templates/faoitaly/documents/pdf/pdf_Food_Security_Cocept_Note.pdf.
18 UN GA Resolution 217/A (III), U.N. Doc A/810 at 71 (1948).
19 Rome Declaration on World Food Security and World Food Summit Plan of Action. World Food Summit. Rome (1996), online http://www.fao.org/docrep/003/w3613e/w3613e00.htm.
20 The State of Food Security and Nutrition in the World: Building Climate Resilience for Food Security and Nutrition. FAO IFAD, UNICEF, WFP and WHO Report (2018), at p.6. Online http://www.fao.org/3/I9553EN/i9553en.pdf.
21 UNGA Resolution Transforming our World: the 2030 Agenda for Sustainable Development (21 October 2015) A/RES/70/1, available at: http://www.refworld.org/docid/57b6e3e44.html.

practices set up and executed in holistic and integrated way.[22] Sustainable agriculture practices should result in boosting yields, wise management of scares water resources, reversing land degradation, correct use of nutrients and smart pest management. Achieving synergies and adequately address trade-offs among agriculture, water, energy, land and climate change is impossible without increased use of integrated decision-making processes at all levels.

The most significant hurdle to achieving sustainable development goals is their implementation by individual states and international community together. In order for sustainable agricultural production to become the operating standard, elements of sustainable agriculture have to be made mandatory. For this, it is essential that individual countries fully integrate the requirements of the UN Sustainable Development Goals into their policies and include in the applicable regulatory framework.[23]

Integrated space applications can bring substantial benefits to advance this important area and goals associated with it. Agricultural production follows seasonal patterns related to the biological lifecycle of plants, depends on the physical landscape (e.g., soil type), climatic driving variables, and agricultural management practices. The productivity can change within short time periods due to unfavourable growing conditions. This necessitates timeliness of data and information provided to and by agricultural monitoring systems. FAO underlines the need for timeliness in providing agricultural statistics and associated monitoring systems[24] in order to address the issues of food security in the most efficient and effective way. Satellite systems, particularly EO satellites generate data constantly, and provided value-added activities are performed in a timely fashion, can address the timeliness need.

Due to the capability to provide global coverage, at different resolutions and with various sensors, satellite EO data and information derived from the them permit decision makers to better anticipate the effects of negative climatic events, and conduct better risk assessments based on unbiased spatial picture over large areas. Specifically for agricultural purposes, this translates in the ability to better understand possible effects of climate change, to find best approaches to mitigate them, and to identify areas with the highest yield potential.[25]

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22 Food Security, Nutrition and Sustainable Agriculture. UN Sustainable Development Knowledge Platform, online https://sustainabledevelopment.un.org/topics/foodagriculture.

23 Michail Kritikos, Precision Agriculture in Europe: Legal, Social and Ethical Considerations. European Parliament Study (November 21017), at p. 22.

24 Clement Atzberger, Advances in Remote Sensing of Agriculture: Context Description, Existing Operational Monitoring Systems and Major Information Needs. *Remote Sens*. 5 (2013) 949-981, at p.950.

25 Clement Atzberger, Advances in Remote Sensing of Agriculture: Context Description, Existing Operational Monitoring Systems and Major Information Needs. *Remote Sens*. 5 (2013) 949-981, at p.957.

Specific areas or activities that can be better managed with information provided by space applications include:

- Crop forecasting (planted areas, yield, production, trade forecasts);
- Weather forecasts and their impacts;
- Pest and drought stresses;
- Famine early warning, food aid and imports;
- Strategic grain reserves.

In addition, dedicated information products and services (e.g. Copernicus land monitoring service) help "facilitate the measurement of environmental performance, the creation of buffer zones, the use of different crop varieties, the strengthening of the knowledge base regarding the pressures of agriculture upon climate, energy, water, waste and pollution, the development of models and algorithms using large quantities of data collected from the small, low-cost and robust field sensors now available, and the establishment of new benchmarking practices for environmental performance."[26]
Last but not least, agricultural practices, being part of anthropogenic pressures, and alongside with and climate change pressures, constitute serious threats to the integrity of the delicate ecosystems of several protected areas, such as national parks, UNESCO World Heritage sites and Natura 2000 sites. Use of satellite EO data and tailored space applications can improve ecosystem models that provide insights as to the dynamics of terrestrial environments, and aim at improving monitoring capabilities for better prediction of short- and long- term impacts of different management strategies.[27]

II.III Agricultural production activities

Some of the activities management of which use of satellite EO data and tailored space application can improve include precision farming, phytopathology, crop management, use of fertilisers and pesticides, field zonation, guided field scouting, forecasting harvest date, irrigation, pest and disease identification. This paper will largely focus on precision agriculture, because it in fact encompasses most of the highlighted activities.
The most characteristic feature of precision agriculture as the site-specific management of crops heterogeneity both at time- and spatial-scale[28]

26 Michail Kritikos, Precision Agriculture in Europe: Legal, Social and Ethical Considerations. European Parliament Study (November 21017), at p. 21.

27 Damiano Pasetto et al. Integration of satellite remote sensing data in ecosystem modelling at local scales: Practices and trends. *Methods in Ecology and Evolution* 9 (2018) 1810–1821, at p. 1811.

28 Alessandro Matese. Intercomparison of UAV, Aircraft and Satellite Remote Sensing Platforms for Precision Viticulture. *Remote Sens*. 7 (2015) 2971-2990, at p.2972.

that enables observing, measuring and responding to inter and intra-field variability in crops. Goals precision agriculture do not differ much from conventional management approaches and focus on enhancing efficiency of agricultural inputs to increase yields, quality and sustainability of productions.
Some of the core elements of precision agriculture management include:[29]

- GPS-guided grid sampling for more accurate soil test data.
- Improved efficiency through variable rate fertiliser application.
- Adjustment of variable rate seeding and variety changes to soil properties for enhanced productivity.
- Use of new technologies for crop scouting for improved field records.
- Tracking spatial and temporal variability in the field with the help of hyperspectral imagery and with “on-the-go” yield monitors;
- Increased cost savings and minimised environmental impact.

Precision agriculture management system is dependent on maps for monitoring weed infestations and coverage, biomass estimation, yield prediction, or crop stress. It is important to generate maps with high positioning accuracy, precise georeferencing and ortho-rectification.[30]
Besides its purpose of improving agricultural practices and increase production, precision agriculture can actively contribute to food security and safety by contributing to generation of (digitalised) roadmaps describing plant and animal products life cycle, from farmers through distribution chain to consumers. Use of improved tracking, tracing and documenting tools and services alongside geo-referencing and digitisation of most of data and activities, precision agriculture results in more transparent farming with readily available information regarding best and applied production practices as well as about crop health.[31]
Since today the choice for adopting precision agriculture as the working management systems is made by farmers themselves (as opposed to being imposed by sector standards or regulatory obligations), the tools that enable adoption and execution of precision agriculture need to be useful, accessible and available to the farmers.

29 Pascal Michel. Space Sciences for the benefit of society. Presentation (November 19, 2015, Vienna, Austria), slide 19. Online http://www.unoosa.org/documents/pdf/hlf/1st_hlf_Dubai/Presentations/47.pdf.

30 Gonzalo Pajares. Overview and Current Status of Remote Sensing Applications Based on Unmanned Aerial Vehicles (UAVs). *Photogrammetric Engineering & Remote Sensing* 8 (April 2015) 14, 281–329, at p.294.

31 Michail Kritikos, Precision Agriculture in Europe: Legal, Social and Ethical Considerations. European Parliament Study (November 21017), at p. 27.

III. Elements of legal framework for integrated space applications

This section briefly outlines main features or elements of regulatory regime relevant to production of integrated space applications and delivery of corresponding services. For the purposes of this paper, the following areas and their regulation are the most important to highlight: generation and access to satellite EO data, satellite navigation, geographic information systems, data processing and fusion, and technological control, human safety, civil liability and privacy.

III.I Earth Observation data

Success of a satellite EO mission (both for satellite operators and data users) depends on several factors, including successful design, operations, data acquisition strategy, its capacity for archiving, cataloguing, caring for data.[32] One of the most crucial issue regarding satellite EO data is discoverability of and access to them that is conditioned by the data access policy of EO satellites' owner or operator. Without access to data any activities regarding data processing and dissemination of its results is impossible. Since data are intangible, access to them is normally provided through licences. The content of a licence is determined by the owner or rightsholder of the data. Licences may grant substantial rights with regard to possible uses of data by the licensee or restrict them to e.g. just viewing.

Open data trend has become very strong over the past decade with ever more governments and private sector[33] releasing their data for unrestricted reuse and distribution. Dissemination and sharing of satellite EO data has been influenced by this trend as well, with more governments declaring observations from their national (or regional) satellite EO missions as freely and openly available (e.g. the flagship US Landsat and European Copernicus and efforts undertaken by the Group on Earth Observations[34] on the global level).[35] The open data policies and corresponding regulatory frameworks require use of more open licences that allow data processing and generation of derivative works. However, licencing conditions may vary widely thus

32 Alan S. Belward, Jon O. Skøien. Who Launched What, When and Why; Trends in Global Land-cover Observation Capacity from Civilian Earth Observation Satellites. *ISPRS Journal of Photogrammetry and Remote Sensing* 103 (2015) 115–128, at p.125.

33 Declan Butler. Many eyes on earth. Nature (2014) 505, 143–144, online https://www.nature.com/news/many-eyes-on-earth-1.14475.

34 GEO Strategic Plan 2016-2026: Implementing GEOSS (2015), online https://www.earthobservations.org/documents/GEO_Strategic_Plan_2016_2025_Implementing_GEOSS.pdf.

35 Catherine Doldirina, Open Data and Earth Observations: The Case of Opening Up Access to and Use of Earth Observation Data Through the Global Earth Observation System of Systems, 6 (2015) *JIPITEC* 73.

creating the issue of legal interoperability of data in general and satellite EO data in particular.[36]

III.II Satellite navigation

Global navigation satellite systems (GNSS) are systems of satellites which provide continuously optimized location and time information, transmitting a variety of signals on multiple frequencies available at all locations on Earth.

Use of direct georeferencing has become a feature of Earth observation activities: except for small satellites, most sensors are equipped with a GPS sensor today.[37] Imaging and navigation sensors are increasingly used together.[38] Image based navigation services have two main components: "image matching … of photogrammetry and robotics/computer vision fields, and establishing the sensor spatial relationship at different times that is coming from the photogrammetry and robotics fields."[39]

The major issue to highlight in relation to the GPS, is that because it is a very weak signal, it is vulnerable to interference, whether intentional (e.g. jamming) or not (e.g. weather influences). Another aspect to mention is signal precision and accuracy. Other important aspects that may have legal implications include interoperability and standardisation of the various GNSS services, quality of signals and associated services, liability for defective services, eligibility and conditions applicable to provision of different classes of GNSS services (e.g. standard positioning vs. precise positioning service).[40]

III.III Data processing and fusion

Generation of treatment maps for agricultural purposes requires an enormous amount of different types of data (including climate information, satellite imagery, digital pictures and videos, transition records or satellite positioning signals), collected through connected sensors. By virtue of linking and combining data from different sources (e.g. real-time nitrogen sensing or GPS-connected prescription maps) farmers themselves produce many types of data: "agronomic data, financial data, compliance data, metrological data, environmental data, machine data, staff data, personal data, financial data and operational data, including usage data related to inputs such as fertiliser, and other mapping, sensor and related data created or needed

36 Ray Harris, Ingo Baumann. Open data policies and satellite Earth observation. Space Policy 32 (2015) 44-53, at p.51.
37 Charles Toth, Grzegorz Józków. Remote sensing platforms and sensors: A survey. ISPRS Journal of Photogrammetry and Remote Sensing 115 (2016) 22–36, at p. 27.
38 Charles Toth, Grzegorz Józków. Remote sensing platforms and sensors: A survey. ISPRS Journal of Photogrammetry and Remote Sensing 115 (2016) 22–36, at p. 34.
39 Charles Toth, Grzegorz Józków. Remote sensing platforms and sensors: A survey. ISPRS Journal of Photogrammetry and Remote Sensing 115 (2016) 22–36, at p. 28.
40 Education Curriculum on Space Law. UN OOSA (2014), at pp. 69-70, online http://www.unoosa.org/pdf/publications/st_space_064E.pdf.

to operate.[41] Data and information products and services would ideally include also such data to provide tailored applications for specific needs of specific farmers, agricultural communities, regions, etc.

The relevance and importance of legal interoperability is explained by the fact that expert data users often use data from multiple sensors to overcome the fixed temporal and spatial resolutions of single data sources. Data processing and fusion techniques require knowledge of sensor limitations and uncertainties.[42] Lack of legal interoperability[43] may result in the inability to process data obtained from different sources and with different licensing conditions, which is a major concern for data processing, data fusion and generation of tailored integrated space applications, also for agricultural purposes. The task of analysing all relevant licences and of properly reflecting them in the terms and conditions for the value-added product or services may be significant.[44] Therefore, development of simplified and unified licences equally applicable to various types of data is important.

The ways and means of processing data and their visualisation add further implications. For instance, geographic information systems (GIS), Spatial Data Infrastructures (SDI) and advanced Spatial Knowledge Infrastructures (SKI) allow handling integrating visual and other types of data in the digital domain, visualisation of information in various ways, and the simulation of patterns that enhance knowledge.[45] Cloud computing capabilities allow data experts to upscale their algorithms and produce large- scale coverage.[46] Crowdsourcing adds another layer of complexity, if used for generation of integrated space applications.[47]

The figure below substitutes lengthy description of the complexities related to data processing and set-up and operation of various information infrastructures, and serves as an excellent visual summary of the points highlighted in the previous sections.

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41 Michail Kritikos, Precision Agriculture in Europe: Legal, Social and Ethical Considerations. European Parliament Study (November 21017),at p. 14.

42 Damiano Pasetto et al. Integration of satellite remote sensing data in ecosystem modelling at local scales: Practices and trends. Methods in Ecology and Evolution 2018: 9, 1810–1821, at p. 1814.

43 Catherine Doldirina, Open Data and Earth Observations: The Case of Opening Up Access to and Use of Earth Observation Data Through the Global Earth Observation System of Systems, 6 (2015) *JIPITEC*, at pp. 75-76.

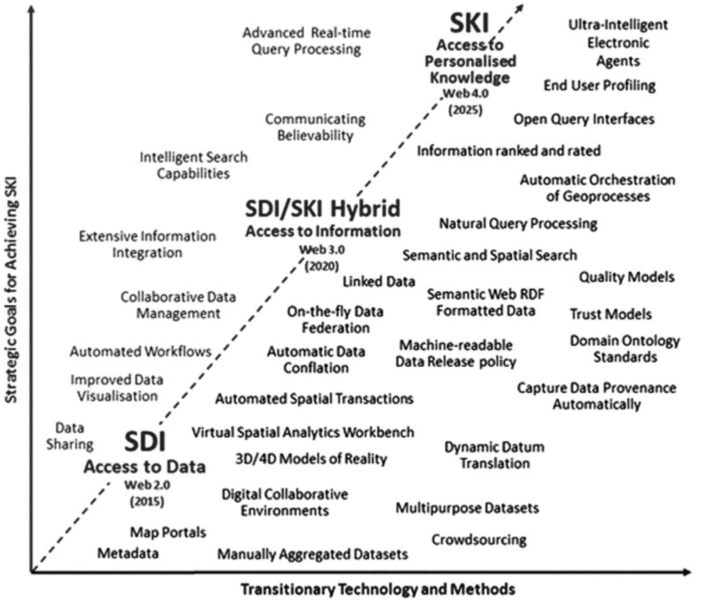
44 Ray Harris, Ingo Baumann. Open data policies and satellite Earth observation. *Space Policy* 32 (2015) 44-53, at p.53.

45 Mukund Raoa, K.R. Sridhara Murthi. Keeping up with remote sensing and GI advances—Policy and legal perspectives. *Space Policy* 22 (2006) 262–273, at p. 263.

46 Damiano Pasetto et al. Integration of satellite remote sensing data in ecosystem modelling at local scales: Practices and trends. *Methods in Ecology and Evolution* 9 (2018) 1810–1821, at p. 1817.

47 Charles Toth, Grzegorz Józków. Remote sensing platforms and sensors: A survey. *ISPRS Journal of Photogrammetry and Remote Sensing* 115 (2016) 22–36, at p. 33.

Figure 1. Transitioning from an SDI to an SKI.[48]



III.IV Cross-cutting issues of technological control, human safety, civil liability and privacy

Quality assurance for data is essential for providing reliable products and services. This issue is linked to the technical aspects of data reliability or trustworthiness that may include technical limitations to data availability in terms of timeliness, technical limitations (frequency, pointing for fee, clouds, accuracy) and resolution.[49] Particularly important for development and delivery of end-user applications is the necessity to signal such limitations and explain their implications. Issues related to responsibility to provide such information and eventual liability are to be explored and addressed, particular in order to enable extensive uptake of integrated space application by the agricultural community and stakeholders.

The ever-increasing resolution of satellite EO data coupled with the navigation and positioning services and more complex processing techniques, raise issues of

48 Peter Woodgate et al. The Australian approach to geospatial capabilities; positioning, earth observation, infrastructure and analytics: issues, trends and perspectives. *Geo-spatial Information Science* 20 (2017) 109-125.

49 Philipp Abbott *et al*. Commercial Value of Satellite Imagery for Agriculture. Presentation. 12th Annual Joint Agency Commercial Imagery Evaluation Workshop (April 16-18, 2013), slide 10. Online https://calval.cr.usgs.gov/wordpress/wp-content/uploads/JACIE-Abbott-April-13.pdf.

data protection; confidentiality/data privacy, censorship and other content-related issues.[50] Specialised information infrastructure applications like land registry, land use, utilities and environmental monitoring may contain personal data or data with far-reaching financial, health or safety consequences. Any misuse or commercial loss resulting from poorly constructed or managed systems will have legal ramifications to the vendors and users.[51]

The needs regarding publication and use of data need to be weighed against personal data protection concerns. While technical criteria including resolution, scale and coverage rapidly change the legal framework remains quite unspecific and uncertainty for both public and commercial data providers as to applicability of data protection laws remains an issue. Current regulatory framework regarding privacy even in the countries and regions with elaborate regimes often does not provide sufficient guidance for cases arising in practice within the field of integrated space applications.[52]

For effective use of integrated space applications, particularly by end-users, hardware is of utmost importance. In the context of globalisation and international trade, compatibility of technologies, hardware and software is an important issue.[53] It can be solved by development and acceptance of uniform standards.

IV. Differences in application of regulatory regime to the three axes

The foregoing section outlined the main legal issues arising from or linked to activities related to integrated space applications, as well as regulatory approaches to their resolution. This section discusses whether there are differences in application of general legal norms to the three axes of agricultural activities described earlier, taking into account their nature, focus and regulatory foundation.

IV.I Compliance with regulatory requirements regarding farming

The constitutive feature of the compliance activities regarding regulatory regime applicable to farming practices is that is mandated by law and enforced by public authorities. Most importantly, this means that availability of necessary data and information products is secured through state funded programmes (i.e. state-run satellite missions like Landsat or Copernicus) or through acquisition of commercially available data generated by private

50 Mukund Raoa, K.R. Sridhara Murthi. Keeping up with remote sensing and GI advances—Policy and legal perspectives. *Space Policy* 22 (2006) 262–273, at p. 268.

51 Mukund Raoa, K.R. Sridhara Murthi. Keeping up with remote sensing and GI advances—Policy and legal perspectives. *Space Policy* 22 (2006) 262–273, at p.268.

52 Ray Harris, Ingo Baumann. Open data policies and satellite Earth observation. *Space Policy* 32 (2015) 44-53, at p.52.

53 Michail Kritikos, Precision Agriculture in Europe: Legal, Social and Ethical Considerations. European Parliament Study (November 21017), at p. 11.

industry. The question in relation to this regards re-usability of acquired data and products: can public authorities responsible for enforcement of compliance with farming requirements use the data for other purposes and make them available for wider use? The approach normally adopted to address this question, is for public authorities to negotiate less restrictive licences that permit use of acquired data beyond the original purposes of enforcing compliance with farming requirements.

It is obvious that the terms and conditions applicable to acquired third-party data need to be respected by relevant public authorities, which means that issues related to copyright, intellectual property protection and legal interoperability of acquired data remain. So do the requirements regarding protection of personal data and information, even though public authorities may have more discretion linked to the possibilities to apply exceptions linked to national security interest, obligations arising from international law, etc.

An issue specific to government-run satellite EO missions is that of continuity and the corresponding responsibility for the enforcement of the established applicable regulatory regime. Another important aspect of enforcement is transparency and equal treatment of both subjects under control (farmers) and third-party data providers (e.g. in establishing fair and inclusive tendering procedures for data acquisition). Last but not least is the issue of outsourcing – when public authorities outsource fulfilment of their responsibilities to private industry: they should be responsible for ensuring that activities thus executed are in compliance with all requirements and under overall control of public authorities themselves.

IV.II Agricultural risk management: food security and sustainable development

As discussed in the relevant section of this paper, the establishment of Global Sustainable Development Goals, that also include the goals related to food security and sustainable agriculture, was led by the UN and took the form of declarations that are considered non-binding source of international law. Therefore, their implementation largely depends on the commitment and efforts of individual countries and international community as a whole. Where corresponding obligations arising from binding international treaty law do not exist, the level of compliance can vary considerably depending on individual country's capabilities and resources. Continuous effort to back the declaratory commitments with the treaty law obligations should be considered a significant step towards ensuring achievement of the Goals. Framework established by some relevant framework treaties and conventions (e.g. the International Biodiversity Convention,[54] International Plant

54 Convention on Biological Diversity. Rio de Janeiro, 5 June, 1992. 1760 *U.N.T.S.* 79.

Protection Convention,[55] or the Rotterdam Convention regarding international trade in pesticides[56]) serves as a worthy example.

Due to the fact that international efforts to achieve specific objectives on a global scale require effective cooperation and coordination, the need for standardisation and harmonisation of data exchange and format is particularly relevant to working towards improved food security and sustainable ways of agricultural production. In addition, it is valuable for countries to exchange information and experience regarding, e.g. their activities pertaining to enforcement (the first axes as described in this paper) so that practices encouraging and ensuring sustainable agricultural production with integrated environmental protection requirements are aligned across national jurisdictions.

Cooperation among states, particularly within the discussed area of activities, needs to extend to data exchange and capacity building to ensure that countries without own EO satellites programmes, access or capabilities can meaningfully benefit from current and future technological achievements and opportunities.[57]

IV.III Agricultural production activities

Facilitation of use of integrated space applications for farming require favourable environment for commercialisation of such activities, and a clear regulatory framework regarding production and delivery of tailored applications. The increasing use of precision agriculture creates an additional challenge for provision of and access to satisfying advisory services. Beyond mere provision of dedicated services, this requires fostering farmers' ability to receive personalised, targeted advice based on integration of data and information they produce with e.g. satellite EO data. Common data standards dedicated tools and training on agricultural data management are required to achieve this.[58]

Streamlined licensing conditions ensuring legal interoperability of data and information integrated in tailored space applications and a clear framework of dealing with issues regarding privacy and personal data protection are indispensable for establishing a vibrant market. Another important aspect

55 International Plant Protection Convention. Rome, 06 December, 1951. 150 *U.N.T.S.* 67.

56 Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade. Rotterdam, 10 September, 1998. 2244 *U.N.T.S.* 337.

57 Philipp Abbott *et al*. Commercial Value of Satellite Imagery for Agriculture. Presentation. 12th Annual Joint Agency Commercial Imagery Evaluation Workshop (April 16-18, 2013), slide 19.

58 Michail Kritikos, Precision Agriculture in Europe: Legal, Social and Ethical Considerations. European Parliament Study (November 21017), at p. 10.

that needs to be addressed is the reliability[59] of products and services and liability of their providers for their deficiencies. The reason for this is that farmers will make decision regarding their production cycle based on the information provided, hence if information is no sufficient or inaccurate, they may suffer damages from underproduction, etc.

High likelihood that data generated by farmers will be integrated in information solutions tailored to their specific needs, necessitates establishing clear framework and conditions regarding its treatment by data integrators and service providers, particularly beyond the purposes of the original service. The rationale for this is threefold: effects of secondary and tertiary uses of this same data, benefits-return to the farmer owning the basic data, pricing of an agricultural integrated space application. Such framework should determine the potential of those who use the farmers' data to direct and control the data sets, as well as profit from their further elaboration and processing.[60]

V. Outlook and Conclusions

Remote sensing is a rapidly advancing technology, mainly driven by imaging sensor developments and endlessly increasing performance of the information infrastructure, including processing, storage and communication.[61] Precision farming and natural resources management, alongside meteorology and climate change, are expected to be one of the promising space applications in wide use by 2030.[62] Turning the expectation into reality requires a variety of actions, including those within the legal dimension, to address issues posed by use of EO satellite data and other space technologies within the activities of the three axes presented and discussed in this paper.

Global impact of agricultural activities and the elements of sustainable development goals regarding food security and sustainable agriculture need to be taken into account even when addressing the needs and enforcing compliance with the existing agricultural production requirements of individual farmers. Some of the suggestions to the necessary actions include:

- Balance efforts towards responding to fundamental human vs. other needs (e.g. private or individual country);

59 Philipp Abbott *et al*. Commercial Value of Satellite Imagery for Agriculture. Presentation. 12th Annual Joint Agency Commercial Imagery Evaluation Workshop (April 16-18, 2013), slide 19.

60 Michail Kritikos, Precision Agriculture in Europe: Legal, Social and Ethical Considerations. European Parliament Study (November 21017), at p. 17.

61 Charles Toth, Grzegorz Józków. Remote sensing platforms and sensors: A survey. *ISPRS Journal of Photogrammetry and Remote Sensing* 115 (2016) 22–36, at p. 22.

62 Space Innovation, OECD Report (2016) at p. 91.

- Establish priorities with regard to actions supporting food security and sustainable agricultural production goals, and a roadmap for their achievement;
- Enhance cooperation among various members of international communities (from the UN to other international organisation, through to individual countries);
- Promote principles of relevance, coherence, sustainability and global perspective.[63]

In the light of ever-increasing data integration and fusion activities, the issue of legal interoperability should be treated as a priority within the corresponding policy and legal actions. In addition, conditions regarding access to and use of satellite EO data, data generally, and derived information products and services shall be streamlined and made less complicated. In rather practical terms, users should be able to visualise information products in simple and accessible way. Operational data processing chains need to be transparent and uniform, in order to allow cross-community and cross-border use. Further efforts are necessary to ensure generation of tailored products and services easily accessible and usable by those engaged in agricultural activities.[64]

63 Pascal Michel. Space Sciences for the benefit of society. Presentation (November 19, 2015, Vienna, Austria), slide 34.

64 Clement Atzberger, Advances in Remote Sensing of Agriculture: Context Description, Existing Operational Monitoring Systems and Major Information Needs. *Remote Sens*. 5 (2013) 949-981, at p.972.