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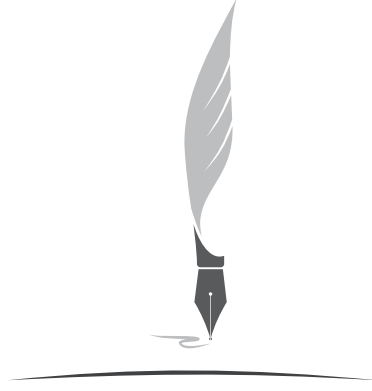
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Academic Studies in Science and Mathematics

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Chapter 2

ADVANTAGES OF THE HYPERSPECTRAL SATELLITE MISSIONS IN REMOTE SENSING SCIENCE

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1. Introduction

Hyperspectral remote sensing can be described to be all systems that are provided remotely sensed data in narrow wavelengths basically. A typical hyperspectral sensor can be recorded the light in a range of 400 – 2500 nm with 20nm sensitivity. However, traditional multispectral sensors can be recorded the reflectance in 100 nm or higher ranges (Thenkabail et al. 2012). High spatial resolution hyperspectral earth observation satellite sensors were started first with Hyperion sensor on EO 1 (Earth Observation 1) platform in 2000s experimentally. Hyperion mission was started by the NASA (Pearlman et al. 2001; Ungar, 2001). Another hyperspectral mission was run by the (European Space Agency) ESA on 22nd October 2001 called CHRIS on PROBA-1 Platform (Satir et al. 2010). Both hyperspectral sensors were samples of the experimental Earth Observation satellite missions.

Nowadays, hyperspectral satellite sensors are served experimentally, and they are provided vital information to planned hyperspectral missions. So they have some limited abilities such as scanning width, signal noise, mid-spectral resolution and periodic data transfer.

There have been many studies on plant ecology, physical analyses, and mining in the literature until today. In general, most of the researches that were used hyperspectral satellite sensors were given more accurate results than multispectral studies. For example, according to the Bannari et al. (2006), was 10% more accurate results than multispectral dataset was obtained using one time hyperspectral dataset on crop pattern mapping and harvest prediction.

Hyperspectral satellites are provided detailed information on plant nutrients, plant water content, pigment and protein content, chlorophyll content, light use efficiency (LUE) soil moisture, Soil organic carbon,

main rock type, ground mineral content, water pollution and surface rock and soil materials. The purpose of the paper is to compare future and current hyperspectral satellite sensors to detect the future contribution of the hyperspectral satellites on soil, plant, water and mining researches.

2. Space Borne Hyperspectral Technologies from Past to Future

Two Hyperspectral experimental satellite sensors have been used widely until today. Hyperion and CHRIS PROBA are two frontiers on hyperspectral earth observation in high and mid spatial resolutions. Additionally, there are some hyperspectral satellite sensors that are used on global scale studies such as HICO, OMI and SCIAMACHI.

The first high resolution hyperspectral satellite has been Hyperion, and it started to provide data in 2000s. This mission was the break point to see the hyperspectral satellite capabilities and problems in application in high spatial and spectral resolution. In addition to high spatial resolution missions, some of the hyperspectral satellite sensors were developed for observing atmosphere, water and environmental variables in global scale.

Today, countries, which are wanted to be frontier in space, have been developed new space borne hyperspectral sensors for commercial and scientific requirements. Only high spectral resolution are not enough to obtain detailed information from the earth surface. Therefore, researches are tried to combine both spatial and spectral abilities in one platform. Particularly, planned missions are focussed on the requirements on spatial resolutions. Also this type of the space borne sensors called 2nd generation hyperspectral satellites. Active and planned space borne hyperspectral sensors are shown in table 1. Planned missions have been adapted from Transon et al. (2018).

HypIRI and HypXIM planned missions are different from other planned missions on spectral and spatial resolutions. When the HypIRI mission will have been launched, it will be the first space borne hyperspectral mission in thermal wavelength. HypXIM is stand out its spatial resolution (8m) (Table 1).

Table 1. Active and planned hyperspectral space borne sensors until 2019

Sensor/ Platform/ Country	Spatial Res.	Spectral Res.	Spectral range (nm)	Swath Width	Expected Launch Date
Active Space borne Hyperspectral Sensors					
HICO/ISS/USA	90m	128	353 – 1080	42km	2009 - Current
OMI/Aura/USA	13X12km	740	270 – 500	145km	2004 - Current
SCIAMACHI/ ENVISAT/ESA- EU	30X60km	~2000	212 – 2384	960km	2002 - Current
Hyperion/EO-1/ USA	30m	220 (196*)	427 – 2395	7.5km	2000 - Current
CHRIS/PROBA/ ESA**	17 – 34m	19 - 64	200 – 1050	17.5km	2001 - Current
Taigong-1/ Shenzhou-8 / China	10 – 20m	128	400 – 2500	10km	2001 - Current
Planned Space borne Hyperspectral Sensors					
HypIRI/USA	30 - 60m	214	380 – 12000	145 - 600km	2020-2021
EnMap/Germany	30m	92	420 – 2450	30km	2020-2021
PRISMA/Italy	30m	250	400 – 2500	30km	2020-2022
HISUI/Japan	20 - 30m	186	400 – 2500	20km	January 2020
HypXIM/France	8m	210	400 – 2500	15km	unknown
SHALOM/Israel- Italy	10 - 20m	275	400 – 2500	30km	unknown

* 196 wavebands calibrated,

** Spectral and spatial resolutions are different based on products.

3. Studies Using Hyperspectral Space Borne Sensors on Plant and Minerals

There are many studies on hyperspectral remote sensing in the literature. In this study, only space borne sensors were considered, and plant, soil, agriculture and mineralogical studies were filtered. More than 200 papers were selected using Web of Science (WOS), Scopus and specific hyperspectral workshop proceedings from 2007 to September 2019. Subjects of the papers were divided according to the paper content, material and methodology. Twenty one specific subjects were defined, and all papers were categorized based on subjects.

Space borne hyperspectral sensors were used on detailed vegetation and crop mapping widely. Studies were concentrated 400 – 2500nm because of sensor specifications. This wavelength range was very important on vegetation and water studies. Therefore, the papers were about on these subjects generally. When multispectral mapping studies were focussed on general Land Use Cover (LUC), hyperspectral mapping studies were about detailed LUC in species scale (level 3 – 4 in CORINE and Anderson). Additionally, accuracy of the maps were higher than multispectral studies significantly (Bannari et al. 2006; Laurin et al. 2016). Hyperspectral space borne sensors are opened a new gate to the vegetation and mineral indices. Laboratory based spectrometer studies are applied to the earth observation because of narrow range detection ability of the space borne hyperspectral sensors. Particularly, vegetation, soil and mineral detection indices were started to use in wide areas to quantify the ecosystem services.

Table 2. 2007 – September 2019 Space borne Hyperspectral Papers in literature on plant, soil and mineral detection

Subject	Total article	Percent
Crop monitoring and pattern mapping	19	8.8%
Vegetation indices	18	8.3%
Detailed vegetation mapping	17	7.9%
Soil chemical properties	17	7.9%
Plant nutrient detection	16	7.4%
Reviews on agricultural subjects	14	6.5%
Comparisons of hyper-multi spectral	14	6.5%
Plant water stress and quantities	12	5.5%
Plant chlorophyllcontent	12	5.5%
Mineral detection	12	5.5%
NPP and crop harvest prediction	11	5.1%
Precision agriculture	9	4.2%
Leaf area index	8	3.6%
Crop and timber biomass detection	8	3.6%
Soil Organic Carbon studies	8	3.6%
Plant diseases detection	5	2.3%
Aridity risk detection	4	1.8%
Soil salinity detection	4	1.8%
Soil and water heavy metal content	3	1.4%
Soil moisture	3	1.4%
Light use efficiency	3	1.4%
Total	217	100%

When we compared the multispectral, hyperspectral space borne and air borne hyperspectral researches, it was clearly shown that hyperspectral space borne studies have been shined with narrow wavelength recording ability with appropriate swath width and cost from all other sensors. Though hyperspectral air borne UAV technologies are developed, hyperspectral cameras are still too expensive, and periodic data obtaining is harder than space borne sensors. In general, basic advantages and disadvantages of the space borne, air borne hyperspectral and space borne multispectral sensors were focussed on table 3.

Table 3. *Comparisons of the multi-spectral, hyperspectral space borne and hyperspectral air borne sensors in general based on literature*

Subjects	Multispectral Space borne	Hyperspectral Air borne	Hyperspectral Space borne
Image pre-processing time	***	*	**
Swath width	***	*	**
Spectral resolution	*	***	***
Spatial resolution	**	***	*
Time resolution	***	*	**
Image classification accuracy (in equal conditions; same level and method etc...)	**	***	***
Related article counts	***	**	*
Image cost	***	*	***
Total mark	20	15	17

(*** stars and * star refer the most appropriate and the poorest performances respectively)

4. Conclusion

According to the table 3, hyperspectral space borne sensors were got the lower mark than multispectral sensor studies because of lack of the articles and spatial resolutions. Planned hyperspectral missions will address this gap over time. Also multispectral space borne sensors will lose importance in the future. Only archive can be kept the importance on multispectral sensors. Another important problem with hyperspectral data is big data processing time. Particularly, multi temporal hyperspectral datasets are included many wavebands. This is a temporary problem because computer technologies

are developed fast, and new image pre-processing and classification softwares and codes have been developed.

There are many hyperspectral space borne studies on image classification, crop and vegetation monitoring, soil and plant chemical components, and reviews of hyperspectral sensors. However, there are lack of studies about soil and water pollution, soil salinity, aridity and plant light use efficiency (Table 2).

Hyperspectral air borne sensors were used mining studies widely instead of space borne hyperspectral sensors because of lack of the hyperspectral satellite and spatial resolution. On the other hand, new space borne sensors will probably use very efficiently in mining studies covering big areas in the future.

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