



## D3.1 Report on Massive Online Open Course and accompanying software system

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**MAIL:** Identifying Marginal Lands in Europe and strengthening their contribution potentialities in a CO<sub>2</sub> sequestration strategy

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## ABBREVIATIONS

Term	Explanation
ACT	American College Test
CDDA	Nationally designated areas
CPD	Continuing Professional Development
DBH	Diameter at breast height
DCL	Data Control Language
DDL	Data Definition Language
DML	Data Manipulation Language
DBMS	Data Base Management System
DBS	Data Banks System
DSS	Decision Support System
ESA	European Spatial Agency
ESDAC	European Soil DAta Centre
GAUL	Global Administrative Units Layer
GEE	Google Earth Engine
GRE	Graduate Record Examination
MIT	Massachusetts Institute of Technology
HH	Horizontal Horizontal
HV	Horizontal Vertical
IMCC	Imperviousness Classified Change



<b>IMD</b>	Imperviousness Density
<b>InSAR</b>	Interferometric SAR
<b>LULC</b>	land-use/land-cover
<b>MLs</b>	Marginal Lands
<b>mls</b>	marginal lands productivity layer
<b>MOOCs</b>	Massive open online courses
<b>MSI</b>	Multispectral Instrument
<b>NCLEX-RN</b>	National Council Licensure Examination - Registered Nurse
<b>NDVI</b>	Normalized Difference Vegetation Index
<b>NIR</b>	near_-infrared radiation
<b>P2PU</b>	Peer-to-Peer University
<b>PCM</b>	Pair Comparison Matrix
<b>QGIS</b>	Quantum Geographic Information System
<b>RADAR</b>	RAdio Detection And Ranging
<b>s</b>	soft layer multiband image
<b>SAR</b>	Synthetic-Aperture Radar
<b>SAT</b>	Scholastic Aptitude Test
<b>SWIR</b>	Short-wave infrared radiation
<b>S2GLC</b>	Sentinel 2 Global Land Cover
<b>TCD</b>	Tree Cover Density
<b>TCDC</b>	Tree Cover Density Change



<b>U.S.</b>	United States
<b>UPV</b>	Universitat Polècnica de València
<b>URL</b>	Uniform Resource Locator
<b>VH</b>	Vertical Horizontal
<b>VIS</b>	Visible wavelengths
<b>VV</b>	Vertical Vertical
<b>WRB</b>	World Reference Base



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## EXECUTIVE SUMMARY

This report provides the scope and detail guidelines of the work carried out in the tasks “Task 3.1 Preparation of a Massive Online Open Course (MOOC) for the use of advanced techniques in MLs' mapping/monitoring” and “Task 3.4 Accompanying Software systems” developed during the **MAIL** project.

The first chapter of this deliverable focuses on the knowledge and experiences gained and the developed methodology during the implementation of the **MAIL** project on Marginal Lands mapping and monitoring for Knowledge sharing. The benefits of Marginal Lands to bioenergy production, serving as carbon sequestration sink, to undoubted ecosystem support has been realized in the recent past, and hence, the need for thorough research and knowledge sharing regarding its definition, mapping and identification, and management is essential. The MOOC runs on Universitat Politècnica de València (UPV) learning platform; UPV[X] an affiliation of *edX* and will also be deployed in AUTH's open courses platform. Considering this, the historical development of available MOOC platforms has been explored, content creation to expected audience's assimilation, evaluation as well as expected learning outcome have also been explored and given consideration in the **MAIL** MOOC. The **MAIL** MOOC can be accessed through the [MAIL project website](#), or by doing a search on the UPV platform[x] or AUTH's open course platform.

The second chapter of this document addresses the description of the software tool development process and the back-end architecture of the web-based software system for marginal land detection. The development of the online platform was a major milestone in the **MAIL** project. It had the goal to gather all methodological developments under a single software environment. This included the development of a spatial open source data base management system (DBMS) to store all intermediate and final products, and a set of spatial analysis tools to perform key computations for mapping and monitoring of marginal lands in Europe.



## 1. MASSIVE ONLINE OPEN COURSE

In the recent past, schooling, skills acquisition, and knowledge sharing have been virtualized with the intensification of Massive Open Online Course (MOOC) adoption in 2008 in the world economy, making it easily accessible by all at all locations (Shapiro et al., 2017). This has resulted in disruption in the traditional educational curriculum with emerging new pedagogy and expectations from both knowledge and skills seekers and their providers. Due to this, there emerged a lot of studies that seek to juxtapose the benefits of the breakthrough in knowledge dissemination and the disruption in academia (Ebben y Murphy, 2014; Shapiro et al., 2017).

The works of Waldrop (2013) denounced the geographical boundary that MOOC breaks to make knowledge available at the convenience of many learners at a shot, interactively, and collaboratively (Moore y Janowicz, 2009). Some educationists like Cooper and Sahami (2013a) or McNutt (2013) on the contrary, bemoaned that the fast adoption of MOOC stands the chance to compromise the existing quality of learning and independent assessment due to the absence of in-person classroom interaction, fieldwork, and experiments.

Researchers such as Cooper and Sahami (2013) or Harder (2013) also alluded to the fact that, even though MOOC is redefining the structure of the traditional educational system in terms of geographical accessibility, cost of enrolment, the requirement for enrolment, pedagogy development, skills level assessment, its current framework of delivery and the challenges of mimicking the in-person interactive and collaborative human learning atmosphere is enough evidence that, it cannot easily replace the former (Fidalgo-Blanco et al., 2015), but may coexist for students to choose based on their circumstances, interest, budget and so on.

It is therefore imperative for stakeholders of MOOC development and improvement to invest the needed resources and effort to be able to stand the current traditional in-person educational pedagogy. This competition will in the end ensure efficiency and overall quality and equal access to both formal and informal education in our societies.

### 1.1 MOOC history

The acronym MOOC was first coined by Dave Cormier and Bryan Alexander (Siemens, 2012) in respect to the first course developed by George Siemens and Stephen Downes in 2008 called “Connectivism and Connective Knowledge”.



The popularity of MOOC was witnessed during the works of Sebastian Thrun (Stanford University) and Peter Norvig (Director of Research at Google) in 2011 when they released the course 'Introduction to Artificial Intelligence'. It got spread to 190 countries with 160,000 students. This success motivated the developers and in 2012, they partnered with Mike Sokolsky and funded *Udacity* for profit-making. *Udacity's* first course; 'Building a Search Engine' was authored by David Evans from the University of Virginia. The next turnaround for *Udacity* was during the course of Professor Anant Agarwal (Massachusetts Institute of Technology); 'Circuits and Electronics', which pulled 120,000 students. *Udacity* increased its enrolment numbers to 314,000 after the outdoor course, 'Introduction to Computer Science'. *Coursera* in May 2012 was founded by Andrew Ng and Daphne Koller (Stanford University) for profit-making. In May 2012, a non-profit *edX* was founded by Harvard University and the Massachusetts Institute of Technology. *edX* online circuit lab course; 'Circuits and Electronics' attracted 370,000 students (Siemens, 2012; Sanchez-Gordon y Luján-Mora, 2014). The year 2013 also saw the emergence of the Iberoamerican region MOOC like MiríadaX. It currently hosts about 57 courses from 20 universities mainly from Spain. There was also, Australia's Open2Study, MOOC with 49 courses from 19 educational universities, United Kingdom's *FutureLearn*, which has 36 courses and 26 universities, and so on.

## 1.2 Types of MOOC

Due to the varying needs of the large MOOC users and their expectations and also the affiliations and rationale of developers, not all the courses adopt the same structure and methodology of delivery (Fidalgo-Blanco y Sein-Echaluce, 2013).

This has led to the classifications as 'xMOOC' and 'cMOOC'. The predominant one is the 'xMOOC', where the developers are domain experts, affiliated to universities and therefore create these learning platforms to reach their students and the general public. The content and their structure are therefore almost the same as the university's traditional delivery system and provide certification as proof of skills acquisition (Bates, 2014; Espada et al., 2014).

The 'cMOOC' has an open structure with the primary aim of knowledge sharing to groups of audience and does not use assessments test. Participants are required to submit their useful suggestions for course content improvement (Bates, 2014; Espada et al., 2014).

Task-based MOOC is the third type where the focus is on students' practice-driven approach in solving exercises and projects. Participants have the flexibility to use

referenced external learning materials to assist them in their progress of studies. The wide participant's community help create virtual group consultations during learning (Espada et al., 2014). Table 1 gives a juxtaposition of cMOOC and xMOOC characteristics in terms of structure, ease of use, accessibility, and pedagogy about the traditional teaching pedagogy.

<b>cMOOC</b>	<b>xMOOC</b>
Connectivism Pedagogy	Traditional Pedagogy
Peer training	The professor is an Authority
Each Participant is a potential facilitator	Top-down information
Collaborative model	Traditional model
Collaborative work	Recorded courses
Peer assessment	Assessment
Open resources	Proprietary resources
Each Participant is a potential facilitator	Top-down information
Collaborative model	Traditional model
Collaborative work	Recorded courses
Peer assessment	Assessment
Open resources	Proprietary resources
Created by learners	Created or bought by professor/organization
Open goals	Predefined goals
Learners define their own goals	Goals are defined by the course designer
Full connectivity	Limited connectivity
Learning together	Access to the course
Co-creation of contents and knowledge	Forum discussion, external downloadable materials
Extended domain	Focus domain
Often transdisciplinary, open to exploration	One discipline or set of topics
No certification	Certification
Badges, self-assessment	Paying certificates

**Table 1: Differences between cMOOC and xMOOC. Source: Bertolini (2017).**

### 1.3 Comparison of MOOC platforms

The motivation that derives learners and teachers alike for MOOC development is much dependent on factors such as size, interest, learners' prior experience, and many other factors (Aldahmani et al., 2020). The study of Watted and Barak (2018) about the



motivation by researchers and students, indicated that students who are affiliated to universities/formal institutions are attracted by improving their skills and been certificated while the rest of the users are driven by deepening and a breasting their skills to the changing demands of the global economy.

These in turn also define different platforms of pedagogic flexibility, development process, cost, institutional support, and expected participants (Aldahmani et al., 2020). It is therefore not surprising that educators are in a conundrum in deciding on the MOOC pedagogic and a comfortable delivery style in meeting both learners' and the educators' needs simultaneously (Smith et al., 2017).

Even though the earliest MOOC of 'Connectivism and Connective Knowledge' did not use any specific platform in its delivery but online aggregators, current ones develop their software to meet their students' demands. In fact, almost all universities now try to reach out to their students and the general public through their existing platforms.

Some MOOC platforms like *Coursera* and *Udacity* are profit-oriented, running on their proprietary software, making them deviate from the initial conception of MOOC as free access. Possibly, the high demands for MOOC with its associated cost of course development and maintenance might have compelled such decisions as a means to monetize the services. These platforms, therefore, require institutions who are interested in running the courses to sign a contract. However, *edX* provides its service for free and has an open-source platform. Accessibility to its platform also requires the signing of a contract. Educational institutions have free access to develop and run their MOOCs (Daniel, 2012).

There are also Platform providers such as *Canvas Network*, *CourseSites* by Blackboard, *P2PU* Peer-to-Peer University, and *OpenClass* which give high education institutions the chance to run MOOCs at no cost. Learning Management Systems like Moodle or Sakai are also used to offer MOOC courses and now more than 300 institutions take advantage of it. These systems have scalability challenges because they were conceived and developed for about 200 students (Daniel, 2012).

Other open-source platforms are available to provide tools for creating MOOCs. The advantage of these tools is that they are scalable and can be reused. An example is *XBlock* which is a component-based architecture to be used by developers in creating the various course sections. This *XBlock* is used by *edX* in their course developments.



Another open-sourced platform is Google CourseBuilder for MOOC development which is now integrated into edX (Daniel, 2012; Dan, 2013).

Table 2 below as provided gives a comparison of the 57 best MOOC platforms concerning; Platform, Location, Launched date, Number of Users, Number of Courses, Free Courses, Paid Courses, Subjects, Certificates, Pathways, Credit, Degree, Course Type, and Language.

The description of Table 2 is given below.

1. **Free Courses:** Free access to all course content including tests & assignments where applicable.
2. **Paid Courses:** Users are required to pay a fee to access all or some of the course content.
3. **Verified Certificates:** E-Certificates with a URL allowing employers or institutions to verify the authenticity of the certificate.
4. **ID-Verified Certificates:** Course certificates issued where the graduate's identity has been verified for tests & assignments.
5. **Pathways:** Series of related courses designed for more in-depth learning.
6. **Credit:** Some MOOC platforms offer either transferable college credit or CPD points on some of their courses. Check the individual course pages for more information.
7. **Degree:** Some platforms offer MOOC-based degrees. Typically, these are based on a "pay as you go model" and are a fraction of the cost of a traditional degree. An application process, as well as minimum requirements, may be necessary.
8. **Scheduled:** A scheduled course typically has a start and an end date, with deadlines.
9. **On-Demand:** An on-demand course can be taken at any time without any deadlines.



Platform	Location	Launched	Nº Users	Nº Courses	Free Courses	Paid Courses	Subjects	Certificates	Pathways	Credit	Degree	Course Type	Language
Saylor Academy	United States	2008	Unknown	100+	Yes	No	Varied	Non-Verified (Free)	Diplomas	College	Yes	On-Demand	English
Cognitive Class	United States	2011	700,000+	50+	Yes	No	Big Data	Non-Verified & Verified Badges (Free)	Yes	No	No	On-Demand	English, Japanese, Spanish, Russian, Portuguese, Mandarin
Canvas Network	United States	2012	Unknown	200+	Yes	No	Varied	Non-Verified (Free)	No	No	No	Scheduled & On-Demand	Mostly English
Coursera	United States	2012	25,000,000+	2,000+	Yes	Yes	Varied	ID-Verified (Paid)	Specializations	College	Yes	On-Demand	Multiple
E-MOOC	Spain	2012	2,200+	11	Yes	Yes	Entrepreneurship	Non-Verified (Free & Paid)	Yes	No	No	On-Demand	Spanish
EdX	United States	2012	14,000,000+	950+	Yes	Yes	Varied	ID-Verified (Paid)	Xseries, Professional Certificate Programs, MicroMasters	College	Yes	Scheduled & On-Demand	Mostly English
Futurelearn	United Kingdom	2012	6,500,000+	400+	Yes	Yes	Varied	Non-Verified & ID-Verified (Paid)	Programs	College	Yes	Scheduled	English
JournalismCourses	United States	2012	115,000+	9	Yes	Yes	Journalism	Non-Verified (Paid)	No	No	No	Scheduled	English, Spanish, Portuguese
MRUniversity	United States	2012	Unknown	15+	Yes	No	Economics	Non-Verified (Free)	No	No	No	On-Demand	English, Spanish
OpenClassrooms	France	2012	2,500,000+	100+	Yes	Yes	ICT	Non-Verified (Paid)	Yes	CPD	Yes	On-Demand	French, English, Spanish
OpenHPI	Germany	2012	Unknown	40+	Yes	No	ICT	Non-Verified (Free)	No	No	No	Scheduled & On-Demand	English, German
OpenLearning	Australia	2012	900,000+	4,300+	Yes	Yes	Varied	Verified (Free & Paid)	Yes	CPD	No	Scheduled & On-Demand	English, Malay
Udacity	United States	2012	4,000,000+	200+	Yes	Yes	Technology	ID-Verified (Paid)	Nanodegrees	No	Yes	On-Demand	English
Zhihuishu	China	2012	10,000,000+	50+	Yes	Yes	Varied	Verified (Free)	No	College	No	Scheduled	Chinese



Platform	Location	Launched	Nº Users	Nº Courses	Free Courses	Paid Courses	Subjects	Certificates	Pathways	Credit	Degree	Course Type	Language
Acumen+	United States	2013	300,000+	31	Yes	Yes	Social Change	No	No	No	No	Scheduled & On-Demand	English
Campus Virtual Romero	Peru	2013	110,000+	30+	Yes	Yes	Business	Non-Verified (Paid)	Yes	No	No	On-Demand	Spanish
Complexity Explorer	United States	2013	Unknown	11	Yes	Yes	Complexity science	Non-Verified (Free)	No	No	No	Scheduled	English
Ewant	Taiwan	2013	20,000+	600+	Yes	No	Varied	Non-Verified (Free) + Certification Exam (Paid)	Micro-Program	College	No	Scheduled	Chinese
FUN-MOOC	France	2013	1,000,000+	330+	Yes	No	Varied	Non-Verified (Free) & Verified (Paid)	No	ECTS	No	Scheduled	French, English, German
IonisX	France	2013	Unknown	200+	Yes	Yes	ICT	Non-Verified (Free)	Yes	Yes	Yes	On-Demand	French
Iversity	Germany	2013	750,000+	50+	Yes	Yes	Varied	ID-Verified (Paid)	Tracks	ECTS	No	Scheduled & On-Demand	English, German
Janux	United States	2013	Unknown	20+	Yes	Yes	Varied	No	No	College	No	Scheduled & On-Demand	English
Kadenze	United States	2013	Unknown	90+	Yes	Yes	Creative Arts	Non-Verified (Free) & ID-Verified (Paid)	Programs	College	No	Scheduled & On-Demand	English
Miriada X	Spain	2013	4,000,000+	690+	Yes	No	Varied	Non-Verified (Free & Paid)	No	No	No	Scheduled	Spanish, Portuguese
MongoDB University	United States	2013	500,000+	15+	Yes	No	Software Development	Non-Verified (Free)	No	No	No	Scheduled	English
Open Course World	Germany	2013	Unknown	15+	Yes	No	Business, Education, IT	Verified (Paid)	No	No	No	On-Demand	German, English
Open Education by Blackboard	United States	2013	Unknown	400+	Yes	No	Varied	No	No	No	No	Scheduled & On-Demand	Multiple
Open2Study	Australia	2013	Unknown	45+	Yes	No	Varied	Non-Verified (Free)	No	No	Yes	Scheduled	English
OpenSAP	Germany	2013	Unknown	130+	Yes	No	ICT	Non-Verified (Free)	No	No	No	Scheduled & On-Demand	English, French, German, Chinese, Japanese, Bulgarian





Location	Launched	Nº Users	Nº Courses	Free Courses	Paid Courses	Subjects	Certificates	Pathways	Credit	Degree	Course Type	Language
Europe	2013	Unknown	190+	Yes	No	Varied	Non-Verified (Free)	No	ECTS	No	Scheduled & On-Demand	Multiple European
Saudi Arabia	2013	600,000+	200+	Yes	No	Varied	Non-Verified (free)	No	No	No	Scheduled	Arabic
United States	2013	Unknown	60+	Yes	No	Varied	Non-Verified (Free)	No	No	No	Scheduled & On-Demand	English
China	2013	7,000,000+	1,000+	Yes	Yes	Varied	Non-Verified (free) & ID-Verified (Paid)	Micro-Degree	College	Yes	Scheduled & On-Demand	Chinese
China	2014	Unknown	600+	Yes	No	Varied	Verified (Free)	No	College	No	Scheduled & On-Demand	Chinese, English
Europe	2014	Unknown	50+	Yes	No	Varied	Non-Verified (Free)	No	No	No	Scheduled & On-Demand	Multiple European
Jordan	2014	1,200,000+	70+	Yes	No	Varied	Non-Verified (Free)	No	College	No	Scheduled & On-Demand	Arabic
Japan	2014	350,000+	20+	Yes	Yes	Varied	Non-Verified (Free)	No	No	No	Scheduled	Japanese
United States	2014	Unknown	11	Yes	Yes	Education	Badges (Free)	Micro-Credentials	CEU	No	Scheduled	English
India	2014	Unknown	160+	Yes	No	Varied	Certification Exam (paid)	No	No	No	Scheduled & On-Demand	English
Japan	2014	Unknown	30+	Yes	No	Varied	Non-Verified (Free)	No	No	No	Scheduled	Japanese, English
Italy	2014	Unknown	27	Yes	Yes	Varied	Non-Verified (Free)	No	No	No	Scheduled	Italian, English
Ukraine	2014	250,000+	75+	Yes	No	Varied	ID-Verified	Yes	No	No	Scheduled & On-Demand	Ukrainian
China	2014	Unknown	1,000+	Yes	No	Varied	Verified (Free)	No	No	No	Scheduled	Chinese



	Location	Launched	Nº Users	Nº Courses	Free Courses	Paid Courses	Subjects	Certificates	Pathways	Credit	Degree	Course Type	Language
World Science U	United States	2014	Unknown	20+	Yes	No	Science	Non-Verified (Free)	No	No	No	On-Demand	English
Athlete Learning Gateway	Switzerland	2015	14,000+	27	Yes	No	Sports	Non-Verified (Free)	No	No	No	On-Demand	English
Chinese MOOCS	China	2015	Unknown	80+	Yes	No	Varied	Non-Verified (Free)	No	No	No	Scheduled	Chinese
Federica.eu	Italy	2015	5,000,000+	75+	Yes	No	Varied	Certification Exam (paid)	No	No	No	Scheduled	Italian
IndonesiaX	Indonesia	2015	Unknown	25+	Yes	No	Varied	Non-Verified (Paid)	No	CPD Points	No	Scheduled	Indonesian
K-MOOC	Korea	2015	60,000+	550+	Yes	No	Varied	Verified (Free))	No	College	No	Scheduled	Korean, English
MéxicoX	Mexico	2015	1,000,000+	100+	Yes	No	Varied	Non-Verified (Free & Paid)	No	No	No	Scheduled	Spanish
Nadrus	Dubai	2015	100,000+	150	Yes	Yes	Professional skills	Non-Verified (Free)	No	No	No	On-Demand	Arabic
Open Education	Russia	2015	460,000+	230+	Yes	No	Varied	Non-Verified (free) & ID-Verified (Paid)	No	College	No	Scheduled	Russian
Open Education	Taiwan	2015	Unknown	250+	Yes	No	Varied	Non-Verified (Free)	Yes	College	No	Scheduled & On-Demand	Chinese
EduOpen	Italy	2016	28,500+	120+	Yes	No	Varied	Non-Verified (free) & ID-Verified (Paid)	Yes	ECTS	No	Scheduled & On-Demand	Italian
Fisdom	Japan	2016	Unknown	20+	Yes	No	ICT	Non-Verified (Free)	No	No	No	Scheduled & On-Demand	Japanese
SWAYAM	India	2016	Unknown	750+	Yes	No	Varied	Non-Verified (Paid)	No	College	No	Scheduled & On-Demand	English, Hindi
ThaiMOOC	Thailand	2017	Unknown	60+	Yes	No	Varied	Non-Verified (Free)	No	College	No	Scheduled	Thai

Table 2: MOOC platform comparison. Source: Lab MOOC (2018).



### 1.3.1 The Most Popular MOOCs

This section presents the most advanced MOOC platforms in terms of popularity, number of courses produced, number of enrolments, accessibility restrictions, and mode of delivery.

#### 1. *Coursera*

Currently, *Coursera* founded in 2011 by University Sandford professors is the most popular MOOC with the goal of taking education to all parts of the world. It initially started with only the English language but now has courses also taught in other languages like German, Spanish, Chinese, French, and Italian. Its strong partnership with universities throughout the world has facilitated 76 million registered users with more than 630 active courses. Accessibility to most of the courses is through payment but relatively cheaper than the cost of the traditional school system. It awards professional certificates to nano degree programs, micro masters, and standard degree programs (Sanchez-Gordon y Luján-Mora, 2014; Coursera, 2021).

#### 2. *edX*

Edex is the second popular MOOC platform founded in March 2012 by the Massachusetts Institute of Technology (MIT) and by Harvard University with more than 40 universities and institutions collaborations globally. Even though it is open-sourced platform, its usage still demands some recurrent expenses on installation and maintenance. It has also courses taught in other languages apart from the dominant English language. There are currently more than 200 certificated courses (professional, degree and masters) with an enrolment of 35 million (Sanchez-Gordon and Luján-Mora, 2014; *EdX*, 2021).

#### 3. *Miriadax*

The third popular MOOC platform is the Ibero-American *Miriadax* platform, founded by Santander Bank and Telefónica enterprise in 2013. It has about 100 open courses focusing on large themes. Its partner universities are drawn from mainly Spain and other Ibero-American countries. It currently has more than 90 courses and enrolment of 6 million users (Miriadax, 2021).



#### 4. *Udacity*

*Udacity* is the fourth popular MOOC platform that is profit-oriented founded in 2001 by Sebastian Thrun, David Stevens, and Mike Sokolsky. It thus provides both open MOOC and commercial ones for tuition fees payment. It has a partnership with several universities worldwide. Currently, it has more than 4 million students and over 40 active courses.

#### 5. *Udemy*

*Udemy* was founded in May 2010 by Eren Bali, Gagan Biyani, and Oktay Caglar. It is a private MOOC platform providing the opportunity for individuals who have the passion and skills to share online for either free of access or charging a token.

The principal courses in this platform are programming-related, and photography. Currently, it has more than 44 million students, 183,000 courses, and 65,000 instructors teaching courses in 75 languages. In all, it has attracted over 594 million course enrollments as of June 2021. In 2013 it engineered course assessment through an app for Apple iOS, extended it to Apple TV in 2016 (Udemy Team, 2016) and Android app in 2020 (Hockenson, 2014).

#### 6. *Canvas Network*

Unlike other platforms, *Canvas Network* offers its courses for free and is self-paced. From its launch in 2013, it has produced more than 400 courses delivered by over 150 institutions worldwide. It focuses on professional development courses for teachers, school administrators, and other stakeholders. Courses offered range from supporting women's STEM education to research data management for librarians. Students can access MOOCs in English, Chinese, Portuguese, and Spanish. Educators have the opportunity to enjoy the open license by reusing content and sharing freely (Chinh, 2020).

Aside, students can take general paths like enrolling in a series of courses such as deep learning and Scala programming and enjoy the available virtual lab that helps students to practice what they have learned (Cangiano, 2017).

#### 7. *FutureLearn*

*FutureLearn* was founded in 2012 by their partner universities such as King's College London and the University of Leeds. It has in its catalog 418 courses like digital product



management, ecology and wildlife science, and the future of globalization. It provides low-cost academic programs leading to the award of Bachelor of Arts in international business or a Master of Science in cybersecurity. It provides students direct contact with instructors during learning and a quasi of the traditional pedagogy (Chinh, 2020).

#### 8. *Iversity*

*Iversity* is a German-based MOOC platform founded by Jonas Liepmann and Hannes Klöpper in 2015 with a partnership with companies, nongovernmental organizations, and universities in Europe. It has over the years increased its enrolment to over 60,000 since 2015 and developed more than 60 courses in English, German and French. Even though accessibility is free it offers intensive "Pro" courses that require students to pay a tuition fee. It also extends services to corporate entities for training services through its "iversity for Business" initiative (Chinh, 2020).

#### 9. *Kadenze*

*Kadeze* MOOC platform was founded by Jordan Hochenbaum, Perry R. Cook, Owen Vallis, Ashok Ahuja as an opportunity to give prominence to music, visual arts, creative technology, and the likes that were somehow not covered by online course evolution. It can boast of 18 institutional support including Princeton University and the Rhode Island School of Design. *Kadeze* is free but in-depth feedback and premium content are paid for. It has specialization courses to imbibe mastery skills in students for career domain takeover (Chinh, 2020).

#### 10. *Khan Academy*

*Khan Academy* MOOC platform was founded by Sal Khan in 2008 which seeks to democratize education by offering its courses for free. It does focus on large part supports K-12 students support, with content for pre-algebra, English language education, AP chemistry, and U.S government and civics. There are also provisions for preparatory standardized exams like SAT, ACT, GRE, NCLEX-RN, and even the Praxis exams. Parents and teachers have the opportunity to assign and track students' progress for redirection (Chinh, 2020).

### 1.4 Current status of MOOCs

The usage of MOOCs for both learners and teachers in contemporary times has been huge (Ebner et al., 2020) partly due to the recent world over Covid-19 pandemic which



has imposed limitations on mobility (Sun, 2020), and thus creating the necessity for virtualizing knowledge sharing and learning in particular.

The popularity of MOOC is dated in 2012 after the work of Aldahmani *et al.* (2020) which pulled more than 160,000 attendees. As a result, any online course which is open to everyone; online accessible, modulated in the framework of time to start, and to end, duration, updates of content, and most importantly, has an audience of more than 150 is classified as MOOC.

Recently, MOOC content depth, organization, and captioning have played a role in increasing interest and hence numbers of enrolment. For instance specializations courses offered by *Coursera*, Micro Masters by *edX* and Certified Masters programs by Analytics have attracted most learners and confidence in MOOCs' impact in knowledge sharing (Borrella *et al.*, 2019). The value of these innovative programs is evident in their acceptability by employers and even universities as credit waivers for students in some instances (Littenberg-Tobias y Reich, 2018, 2020).

Due to the wide acceptance of MOOCs and their convenience for both learners and teachers (Pozón-López *et al.*, 2020), many studies evolved over the years to evaluate its sustainability and effectiveness (Zulkifli *et al.*, 2020). The finding works of Pozón-López *et al.* (2019), Aldahmani *et al.*, 2020 and Dai, Teo and Rappa (2020) established that less than 10% of students who use MOOC complete successfully partly due to the quality of the content, ease of understanding, the ease of use of the MOOC platform itself, among others. The contribution of Borrella, Caballero-Caballero and Ponce-Cueto, (2019) explored the MOOC usage hurdles and predicted causes with interventions to save the situation. Issues like the need to increase the sense of social integration during learning, integration of prompt and interactive discussion forums among learners and teachers were recommended.

The recent information from Class Central (a company that tracks MOOC development) indicated that *Coursera* been the largest MOOC provider increased its enrolments to nearly four times the number of newly registered users from 8 million in 2019 to 31 million in 2020. It is estimated that currently registered students stand at 76 million (Sanchez-Gordon y Luján-Mora, 2014). The second-largest MOOC, *edX*, doubled its size from 5 million in 2029 to 10 million registered users in 2020. It is also estimated to have current users of 35 million. In the same way, *FutureLearn* enrolment increased from a 2019 figure



of 1.3 million to 15 million in 2020. It is estimated to be around 15 million currently (Sanchez-Gordon y Luján-Mora, 2014).

According to (Schaffha, 2021), before the Covid-19 pandemic, MOOC users enrolments of courses focused on technology-related, business, and career development were dominant, but now, the focus is on Art and design, self-improvement, the humanities, communication skills, health & medicine, and foreign languages. The current most popular enrolled course is that of Yale University; The Science of Well-Being with 2.5 million users (Sanchez-Gordon y Luján-Mora, 2014).

### **1.5 Student experience and pedagogy**

Due to the wide acceptance and integration of MOOCs in the educational system, users' experiences become pivotal to MOOC designers as a means to generate feedback for restructuring their methodology to be able to stand at par if not to out-compete the traditional pedagogy (Shapiro et al., 2017). In view of this, scholars such as Lundqvist, Liyanagunawardena and Starkey (2020) proposed the use of sentiment analysis to understand MOOC users' interests and concerns behind their online comments and actions.

Most MOOC users are happy with the comfort that it brings in giving them the flexibility to organize their learning paths, irrespective of their location. According to Hadavand, Gooding and Leek (2018) this creates the opportunity to take up some job responsibilities for instance along their learning curve. The reproductive role of women which mostly disrupts their schooling and knowledge acquisition is catered for with the geographic comfort, and time convenience that MOOC presents.

Internet, the medium through which MOOC is delivered is not available to all. Only about one-third of the world's population has internet access. South Sub-Saharan countries, for instance, have less than 10% internet coverage. In the opinion of Sanchez-Gordon and Luján-Mora (2014)(Sanchez-Gordon y Luján-Mora, 2014), because internet access is always not available in most developing countries especially and not stable, course materials should be made downloadable for offline access. This will help reduce the massive dropouts rate of MOOC users.

Even though the current MOOC pedagogy creates discussion forums during course enrolments, the organic traditional classroom interaction and collaboration are missing, and thus future improvements should be geared towards making online learning

enrolment's interaction and collaboration a virtual reality (University of Illinois Springfield, 2021).

Also, disabled MOOC users in particular decried that the current framework design does support them to seamlessly follow and thus advocate for universal design standards where especially video content captioning and showing transcript of both video and audio are integrated with the pedagogy development (Richter y Krishnamurthi, 2014). The wide acceptance and its rapidly evolving nature require immediate challenges to be given the needed attention to improve participants' experience to ensure its sustainability.

## 1.6 The Rational for the MAIL MOOC

One of the pertinent focuses of **MAIL** beyond methodological developments and conceptualization of Marginal Lands (MLs), is to create an online learning platform to draw technical skills and experiences gained during the project implementation to empower students and researchers in their practical knowledge acquisition adventures in the domain.

Various scientific works on MLs have proven the subjectiveness in its definition and classification (Oosterveer y Mol, 2010; Kang et al., 2013) as the focus primarily is on the purpose of the research and the environment (Kang et al., 2013; Lewis y Kelly, 2014). After several paper reviews and considering the relevance of MLs in carbon sequestration strategy, the **MAIL** project (MAIL, 2020), concluded on a workable definition for MLs as; "Lands with significant, either environmental (biophysical variables) or socioeconomic, constraints and with potential to impact national accounting for C stock, excluding agricultural lands and other valuable areas (protected areas, uses with local importance, etc.)" It is therefore based on this definition that the methodology for the **MAIL** project was developed and consequently this MOOC.

The usefulness of MLs as expounded by Gelfand *et al.* (2013) and Taylor *et al.* (2020) transcends it serving as an ecosystem service to being leveraged for bioenergy production and also harnessing it for carbon sequestrations strategy. This has thus attracted a lot of interest as the world over is leaping on diverse approaches from an individual level to group level (Pickering et al., 2020) to remedy the already glaring negative impact of climate change on humanity (Wynes y Nicholas, 2017; Cohen et al., 2019).



It is in the response to this cradle call that **MAIL** MOOC was motivated to expose students and researchers to additional possibilities in identifying and monitoring of MLs in the European subregion in an interdisciplinary approach that is accessible by all irrespective of geographic location.

In this sense, the main objectives of the **MAIL** MOOC are:

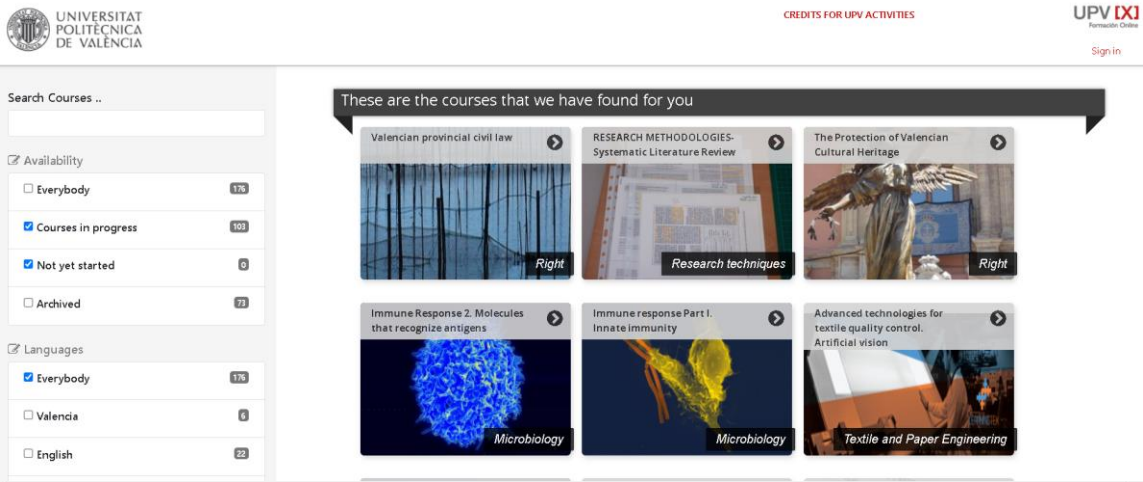
- To create tutorial material covering the processing of remote sensing data to map, classify, and monitor MLs.
- To disseminate the knowledge obtained during the project implementation to the wider public through MOOC on the UPV[X] platform.

## 1.7 The **MAIL** MOOC platform

After various reviews on the suitable platform for the **MAIL** MOOC, the UPV[X] was given considerations. It is owned by the Polytechnic University of Valencia with a wide course focus and offers its free service without payment. Course content is managed and designed with Polimedia technology (Turro et al., 2010; Wikipedia, 2021); a system capable of creating high-resolution multimedia content in a very fast and cheap. The UPV[X] courses are delivered in English, Spanish, and Valencia. The rationale for the choice of UPV[X] over other MOOC platforms is because, the university itself is one of the partner institutions and the lead for the development of **MAIL** MOOC and therefore the privilege to use their system for the test run of the MOOC, after which it is hoped that edX; its affiliated bigger platform will also be used to be able to reach out to a larger audience when the quality of the content and its resourcefulness meet the standard of later. It is partly also because the **MAIL** project is aimed to offer courses free of charge and thus the chosen platform. The Aristotle University of Thessaloniki will also deploy the developed MOOC in its open courses platform.

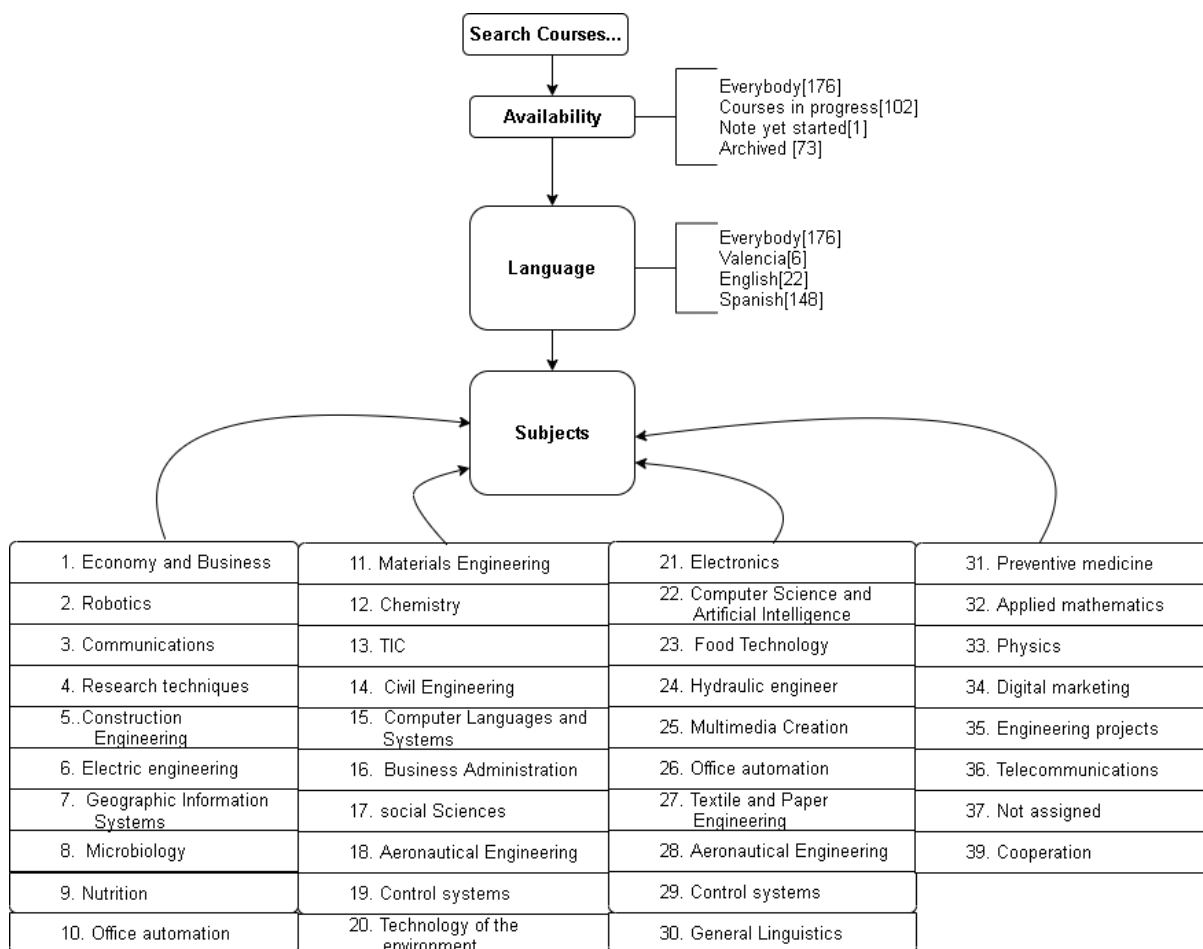
### 1.7.1 The UPV[X] Platform

The UPV[X] is designed to give learners the flexibility to start learning at their own pace and lifelong access to a growing community for support. A graphical interface with some available courses for enrolment is seen in Figure 1.



**Figure 1: Graphical interface of the UPV[X] MOOC Platform.** Source: (Universitat Politècnica de València, 2021).

The UPV[X] interface provides a filter for course search by the availability of the course, the language of instruction, and domain/subjects of interest choice. Figure 2 presents a schematic view of the interface. Duration of courses ranges from 2 weeks effort to 10 weeks depending on the depth of the subject. Table 3 presents a list of active courses, their duration, and domain.



**Figure 2: Interface of the UPV[X] MOOC Platform MOOC. Source:** (Universitat Politècnica de València, 2021).

The interface of the platform provides a course search filtering by referencing their subject or domain areas in (Figure 2) making it easier for students to easily select their area of subject interest for enrolment. The UPV[X] is a multidisciplinary MOOC platform with a current subjects/domain of 39 (Figure 2). Courses developed from these domains range from humanities to applied sciences and engineering as shown in Table 3.



Number	Course name	Duration	launch date	Subject
1	Preparation level C1 (Sufficiency) of Valencià	8 weeks	2021-11-06	General Linguistics
2	Preparation level C2 (Superior) of Valencià	8 weeks	2021-09-27	General Linguistics
3	Preparation level B2 (Intermediate) of Valencià	8 weeks	2021-09-20	General Linguistics
4	Introduction to construction procedures for the improvement of land in civil works and buildings	8 weeks	2021-07-27	Construction Engineering
5	Fundamentals of digital marketing	4 weeks	2021-07-06	Digital marketing
6	Digital marketing in social networks	3 weeks	2021-07-06	Digital marketing
7	First steps in Thermodynamics	3 weeks	2021-07-06	Physical
8	Asset valuation by multi-criteria methods	3 weeks	2021-07-06	Business Administration
9	Get started with Power BI for business	4 weeks	2021-04-29	Office automation
10	Advanced engineering materials derived from composite laminates	5 weeks	2021-02-23	Materials Engineering
11	How to diagnose my innovation competencies	6 weeks	2020-09-08	Economy and Business
12	Initiation to environmental impact assessment	7 weeks	2020-09-08	Technology of the environment
13	Leadership for middle managers	6 weeks	2020-09-08	Economy and Business
14	How to Implement Process Improvement Groups	8 weeks	2020-09-08	Economy and Business
15	Electromagnetism Fundamentals for Engineering	7 weeks	2020-07-14	Physical
16	Sustainability in Architecture: An Interdisciplinary Introduction	4 weeks	2020-07-07	Construction Engineering
17	MOOC Introduction to Technologies for Education technologies-for-education	6 weeks	2020-06-30	Multimedia Creation
18	Mathematical Bases: Integrals	5 weeks	2020-06-23	Applied Mathematics
19	Chemical reactions and stoichiometric calculations	4 weeks	2020-06-23	Chemistry
20	Introduction to Technologies for Education	5 weeks	2020-06-23	Internet Technologies
21	Applications of Graph Theory to Real Life (II)	4 weeks	2020-06-16	Applied Mathematics
22	Python: learn to program	8 weeks	2020-06-09	Computer Languages and Systems
23	Spatial Sound and 3D	6 weeks	2020-06-09	Sound engineering
24	Introduction to game development with Unity	6 weeks	2020-06-02	Computer Languages and Systems
25	Android: Introduction to Programming	10 weeks	2020-06-02	Computer Languages and Systems
26	Fundamentals of Mechanics for Engineering	6 weeks	2020-06-02	Physical
27	MOOC Fundamentals of mechanics for engineering fundamentals-of-mechanics-for-engineering	6 weeks	2020-06-02	Geographic Information Systems
28	Chemical bonding and molecular interactions	4 weeks	2020-05-26	Chemistry
29	Mathematical Bases: Algebra	4 weeks	2020-05-26	Applied Mathematics
30	Evaluation of footballers with the AHP method	3 weeks	2020-05-26	Business Administration
31	Optical Communications Fundamentals	7 weeks	2020-05-26	Communications
32	Applications of Graph Theory to Real Life (I)	4 weeks	2020-05-26	Applied Mathematics

[D3.1] Report on Massive Online Open Course  
and accompanying software system



Number	Course name	Duration	launch date	Subject
33	Mathematical Bases: Derivatives	4 weeks	2020-05-19	Applied Mathematics
34	Formulation and nomenclature of chemical compounds	4 weeks	2020-05-19	Chemistry
35	Rural depopulation. Problems and solutions	5 weeks	2020-04-21	social Sciences
36	Musical creation with Soundcool: Introduction	5 weeks	2020-04-14	Multimedia Creation
37	Introduction to Office 365	6 weeks	2020-04-07	Office automation
38	Fundamentals of Oscillations and Waves for Engineering	5 weeks	2020-03-31	Physical
39	Introduction to stock investing	2 weeks	2020-03-24	Economy and Business
40	Search the Internet	7 weeks	2020-03-24	Office automation
41	Mathematical Bases: Numbers and Terminology	4 weeks	2020-03-24	Applied Mathematics
42	Participatory Management	8 weeks	2020-03-24	Economy and Business
43	Introduction to the Structure of Matter	4 weeks	2020-03-24	Chemistry
44	Diffraction networks in optical communications	5 weeks	2020-03-24	Communications
45	Dynamics and Control	6 weeks	2020-03-10	Control systems
46	SDG in the United Nations 2030 Agenda: Challenges of the Sustainable Development Goals	6 weeks	2020-03-10	Cooperation
47	Basic Spanish 3: Getting there	4 weeks	2020-02-11	General Linguistics
48	Introduction to video game development with Unity	6 weeks	2020-02-04	Computer Languages and Systems
49	Upper-Intermediate English: Technology Today	4 weeks	2020-01-28	General Linguistics
50	Structural UML Diagrams for Software Engineering	5 weeks	2020-01-14	Computer Languages and Systems
51	Advanced Excel: data import and analysis	5 weeks	2020-01-14	Office automation
52	Airport engineering: Airside design according to ICAO (ICAO)	7 weeks	2020-01-14	Aeronautical Engineering
53	Introduction to ALT - Assistive Life Technology	4 weeks	2020-01-14	Preventive medicine
54	IT Fundamentals for Business Professionals: Hardware	4 weeks	2020-01-07	TIC
55	IT Fundamentals for Business Professionals: Software development	4 weeks	2020-01-07	TIC
56	IT Fundamentals for Business Professionals: Programming	4 weeks	2020-01-07	TIC
57	MOOC IT Fundamentals for Business Professionals: Programming clep-information-systems-computer	4 weeks	2020-01-07	TIC
58	Excel: Data Management	6 weeks	2020-01-07	Office automation
59	Redox reactions in industry and nature	6 weeks	2020-01-07	Chemistry
60	ICT Fundamentals for Business Professionals: Hardware	4 weeks	2020-01-07	TIC
61	ICT Fundamentals for Business Professionals: Software Development	3 weeks	2020-01-07	TIC
62	ICT Fundamentals for Business Professionals: Programming	4 weeks	2020-01-07	TIC
63	ICT Fundamentals for Business Professionals: Social Implications	4 weeks	2020-01-07	TIC
64	Technology and aging	3 weeks	2020-01-07	Preventive medicine
65	Upper-Intermediate English: Globalization	4 weeks	2020-01-07	General Linguistics
66	Excel: basics and tools	8 weeks	2020-01-07	Office automation

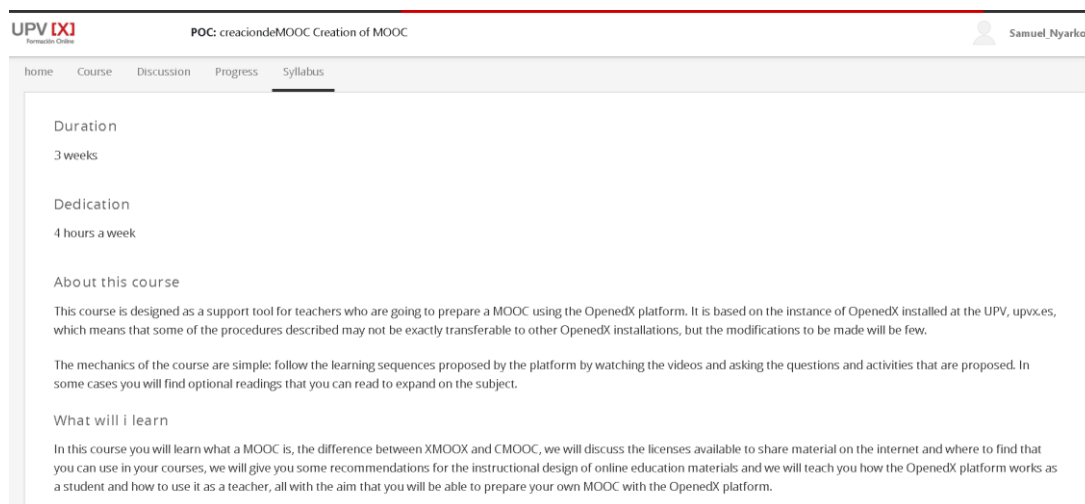


Number	Course name	Duration	launch date	Subject
67	IT Fundamentals for Business Professionals: Enterprise systems	4 weeks	2020-01-07	TIC
68	ICT Fundamentals for Business Professionals: Business Applications	4 weeks	2020-01-07	TIC
69	Salts: chemical reactions and applications	6 weeks	2019-12-10	Chemistry
70	Microcapsules: Application and Characterization	4 weeks	2019-11-26	Textile and Paper Engineering
71	Internet Radio with Podcast: Creation and Basics	6 weeks	2019-11-19	Multimedia Creation
72	Numerical Methods for Math with Octave	5 weeks	2019-11-19	Applied Mathematics
73	Oxidation-reduction reactions: basic concepts	5 weeks	2019-11-19	Chemistry
74	Introduction to photovoltaic solar energy: The photovoltaic module	4 weeks	2019-11-05	Electric engineering
75	Measure and Improve Innovation at the Workplace	6 weeks	2019-11-05	Economy and Business
76	Upper-Intermediate English: Modern Life	4 weeks	2019-11-03	General Linguistics
77	Acids and bases. Chemical reactions and applications	3 weeks	2019-10-29	Chemistry
78	Machine learning and data science	10 weeks	2019-10-29	Computer Science and Artificial Intelligence
79	Introduction to formwork and falsework in civil works and building	4 weeks	2019-10-29	Construction Engineering
80	Upper-Intermediate English: Business	4 weeks	2019-10-29	General Linguistics
81	Design of breakwater levees with cubipods	7 weeks	2019-10-15	Civil Engineering
82	Advanced technologies for textile and fashion industry	8 weeks	2019-10-03	Textile and Paper Engineering
83	Basic Spanish 2: One Step Further	4 weeks	2019-10-01	General Linguistics
84	Audio encoding: Beyond MP3	5 weeks	2019-10-01	Sound engineering
85	Quantitative and Qualitative Techniques for Research	6 weeks	2019-10-01	Research techniques
86	Design effective presentations with Powerpoint	3 weeks	2019-09-24	Office automation
87	Flashdiet: Health and nutrition. Learn to eat healthy.	5 weeks	2019-09-24	Nutrition
88	Intermediate Word: Formatting and Productivity Tools	6 weeks	2019-09-24	Office automation
89	Design, manufacture and program your own robot	6 weeks	2019-09-17	Robotics
90	Technologie et vieillissement	3 weeks	2019-09-17	Preventive medicine
91	Introduction to the Internet of Things (IoT)	6 weeks	2019-09-10	electronics
92	Introduction to the Internet of Things	6 weeks	2019-09-10	electronics
93	Introduction to radiocommunications	5 weeks	2019-09-10	Telecommunications
94	Introduction to project management	5 weeks	2019-06-11	Engineering projects
95	Design of mound breakwaters for feasibility studies. Cubipod® Manual 2016	9 weeks	2019-05-07	Civil Engineering
96	Basic Spanish 1: Getting Started	7 weeks	2019-04-02	General Linguistics
97	Advanced technologies for textile quality control. Artificial vision	4 weeks	2018-10-16	Textile and Paper Engineering
98	Immune Response 2. Molecules that recognize antigens	6 weeks	2018-07-24	Microbiology
99	Immune response Part I. Innate immunity	4 weeks	2018-07-24	Microbiology
100	The Protection of Valencian Cultural Heritage	5 weeks	2018-02-13	Valencian cultural heritage
101	Research Methodology-Systematic Literature Review	6 weeks	2016-03-29	ManagementEducation
102	Valencian provincial civil law	6 weeks	2016-01-12	Civil law

**Table 3: UPV[X] active courses. Source: Personal compilation.**

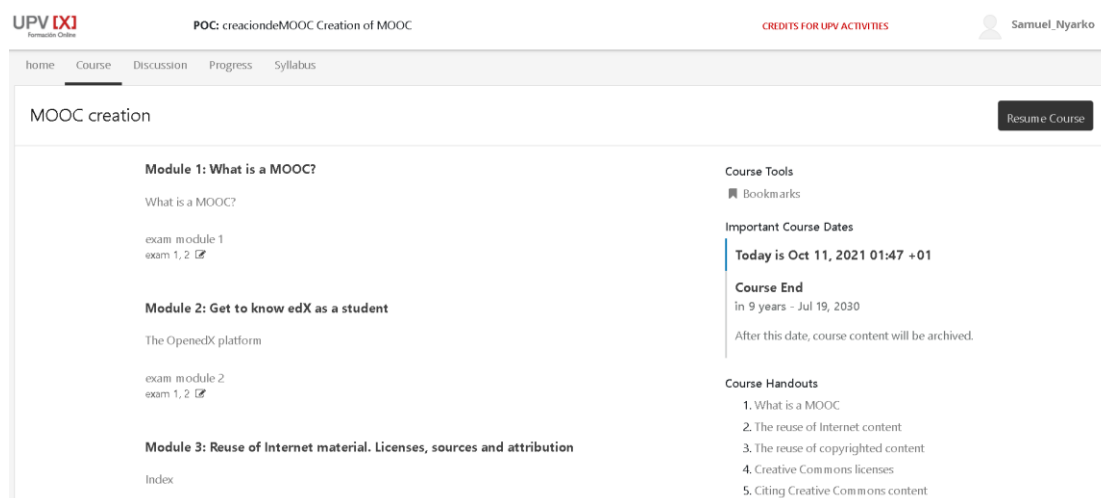
Currently, the platform has no launched course on remote sensing, GIS, or any related geospatial technology application and hence, the **MAIL** MOOC has the chance to pioneer this course.

After a course is chosen or identified by a student on the UPV[X] platform, the syllabus menus present: Information about the duration, an overview of the course, the knowledge to be acquired, prerequisites, the course structure, schedule, and assessment mode and levels. This information is what directs a prospective student's final decision on enrolment and therefore very important (Figure 3).



**Figure 3: Syllabus menu of the UPV[X] MOOC Platform MOOC. Source:** (Universitat Politècnica de València, 2021).

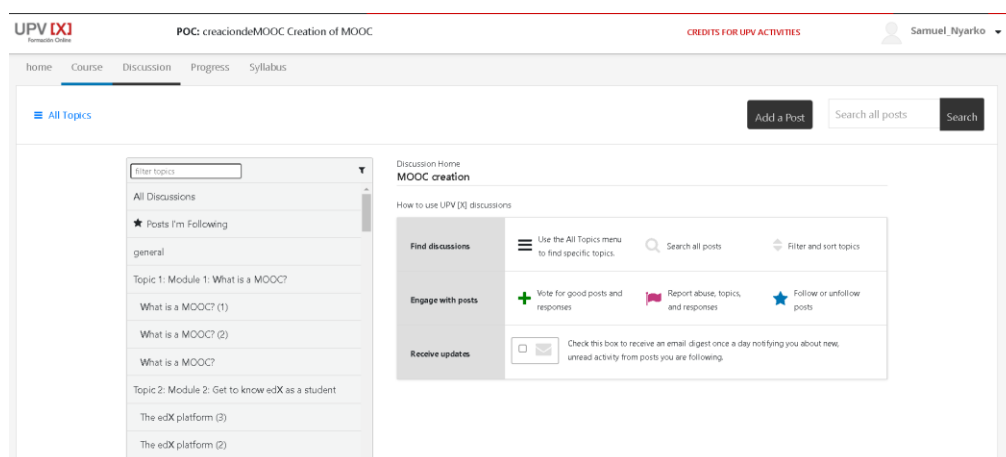
The schedule of the UPV[X] MOOC is structured on modules of weekly tasks, with a lesson lasting between 3 and 10 minutes (Figure 3). Lessons are limited to treating a concept or sub-concepts in order not to cluster students in their learning curve as seen in one of their courses; MOOC creation in Figure 4 below.



**Figure 4: Conceptual course nature of the UPV[X] MOOC Platform. Source:** (Universitat Politècnica de València, 2021).

Like other MOOCs, the UPV[X] has different students evaluation levels. The first one has been the module level evaluation exams, usually, multiple-choice, to help check progress and fix the knowledge acquisition gap. The second assessment is set to determine if the student has achieved the course objective. The combination of the various assessment grade leads to the overall passing of the course (Figure 4).

The discussion forum managed by the course teams offers students to create a link between students and instructors and among students to seek clarification on any doubt encountered or make contributions (Figure 5). This, sort of create a near in-person group learning in a traditional classroom learning virtually.

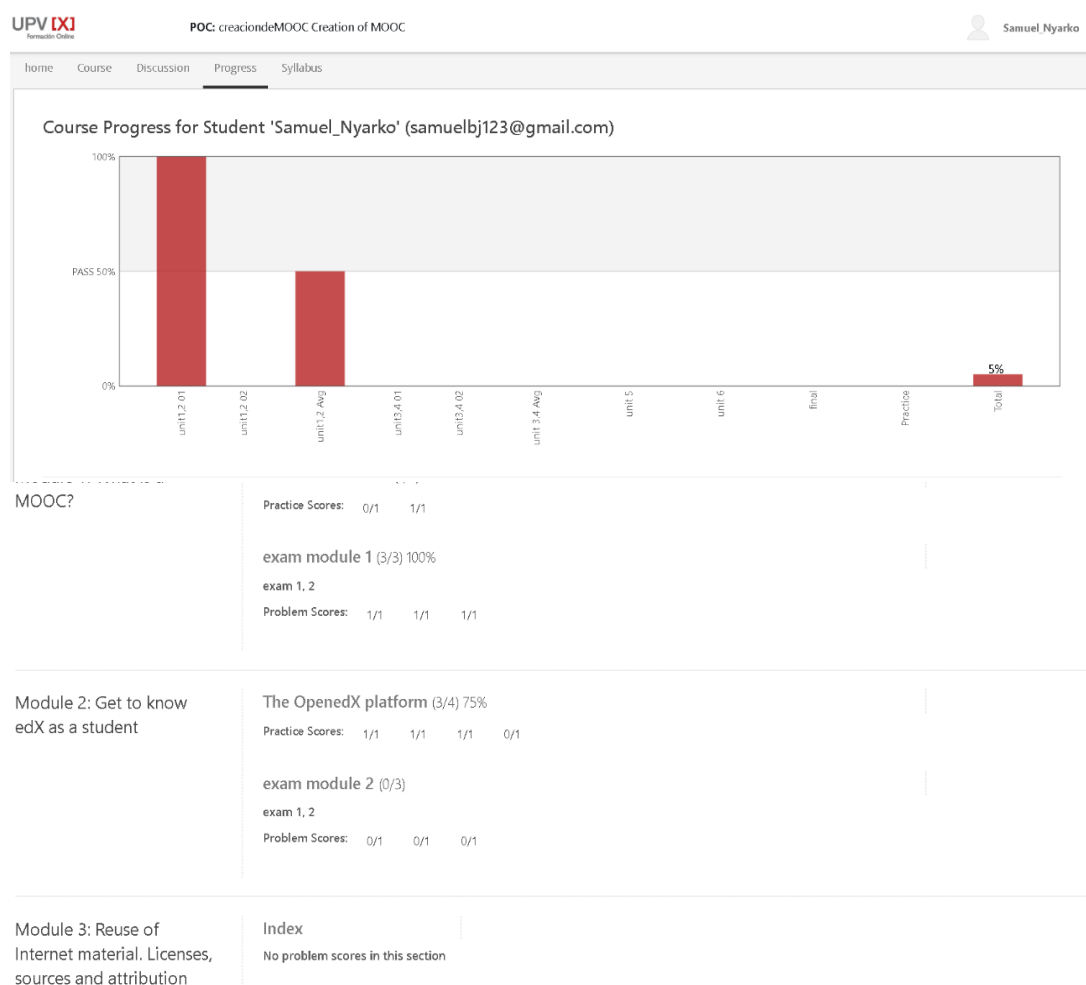


**Figure 5: Discussion forum of the UPV[X] MOOC Platform. Source:** (Universitat Politècnica de València, 2021).



The discussion forum is linked to individual concepts treated in the course and students have the chance to initiate a post to course instructors as well as other colleagues enrolled for their opinion on the doubt at hand. Students who share a similar concern on the already posted topic or doubt can easily follow the activities of the post to be able to get notifications as responses are made.

There is also a Course progress menu that tracks students' activities with respect to various sections and concept completion status, exams taken and the mark obtained. This helps course instructors to be aware of the performance of their students and track their trajectory of learning and assimilation levels (Figure 6).



**Figure 6: Students progress menu of the UPV[X] MOOC Platform. Source:** (Universitat Politècnica de València, 2021).

## 1.8 MAIL MOOC Methodology

The content of the **MAIL** MOOC was created based on the experiences acquired and methodologies developed from the various research tasks during the life of the project. Researchers were put into working groups and tasked to generate the content on agreed guidelines of the MOOC based on their previous responsibility in the **MAIL** project. The UPV[X] platform for MOOC development and hosting was used to deliver the content to the targeted audience. Table 4 shows the sectional development of the MOOC and the referenced previous **MAIL** task as the main source of repository of information, skills, and transferable experiences.

Section	Subsection	MAIL Task
<b>Section 1.</b> <i>Definition &amp; descriptions of MLs.</i>	1.1.- The concept MLs and its synonyms. 1.2.- Definition of MLs. 1.3.- MLs concerns and policies. 1.4.- The classification of MLs over time. 1.5.- Datasets used for characterization of ML.	T2.1.- Literature review on ML def. T2.2.- Collection of appropriate existing European/Global datasets. T5.1.- Best practices MLs monitoring using remote sensing techniques. T5.4.- Success stories on the use of open-source software/ web applications and free sat. data.
<b>Section 2.</b> <i>Identification &amp; classification of MLs.</i>	2.1.- Overall approach for the identification and classification of MLs. 2.2.- Hard Layers for identifying MLs. 2.3.- Soft constrains: Definition and processing. 2.4.- The ML classification scheme in the MAIL project.	T2.3.- Methodology development of m/sm MLs detection.
<b>Section 3.</b> <i>Biomass estimation from remote sensing data.</i>	3.1.- Remote sensing basics (optical, SAR, ALS). 3.2.- Sentinel 2. 3.3.- Sentinel 1. 3.4.- LiDAR.	T2.6.- Estimation. Of biomass volume at low productivity m/sm MLs. T2.7.- m/sm MLs classification in C-sequestration. Capacity groups.
<b>Section 4.</b> <i>Carbon storage and accounting.</i>	4.1.- Direct Methods for carbon storage and accounting. 4.2.- Indirect Methods for carbon storage and accounting. 4.3.- IPCC accounting rules.	T2.5.- Existing models (IPCC, etc.) customization (evaluation, validation, considering local aspects). T4.2.- Quantification of increased C-sequestration. capacity in ML. T4.3.- Estimation of C-stock in forest products.

Section	Subsection	MAIL Task
		T5.3.- Stock exchange market for C-transactions.
<b>Section 5.</b> GEE based platform for MLs management.	5.1.- Map of Marginal Lands in Europe. 5.2.- Carbon calculator. 5.3.- Carbon predictor. 5.4.- Afforestation cost. 5.5.- Multi temporal Marginal Lands analysis.	T2.9.– Web-APP for the management of ML-biomass T3.4.- Accompanying Software systems

**Table 4: MAIL MOOC Content structure and respective MAIL project task. Source: Personal compilation.**

### 1.8.1 Goals of the course

The **MAIL** MOOC seeks to create an online knowledge-sharing platform for students and researchers in the domain of remote sensing applications on ML mapping/classification towards carbon sequestration.

### 1.8.2 Creating background material (documents, presentations, videos, etc.)

#### 1.8.2.1 Introductory videos

An introductory video of every section is made to provide an overview of the section and introduce the facilitator to the audience. This takes about 2-3 minutes. The content of this video is outlined below.

- Name of facilitator.
- Position of facilitator.
- Facilitator's role in MAIL.
- The topics of the lecture and objectives, based on the various subsections to be considered.
- Learning outcomes.

#### 1.8.2.2 PPT presentation videos

The PPT presentation is done (1) with an introduction of the lecturer of about 20-30 seconds, introducing him/herself and describing the main goals of the lecture; and (2) a PPT presentation without showing the presenter, but only audio and the slides. Therefore, the students have at their disposal throughout each section: (1) a series of

theoretical videos where the topic of study is explained in depth, (2) some subsections have practical exercises that allow the student to understand in depth the workflows performed in the **MAIL** project.

#### *1.8.2.3 Further reading materials and reference links*

Scientific papers, published works, and summaries from **MAIL** deliverables where applicable are made available to the audience to complement the theoretical videos and screencasts. Also, YouTube links with 1 K plus followers with a positive recommendation relevant to the topic of discussion are provided. Internet links are also added in the word document under the respective section.

### **1.8.3 Define the evaluation of the contents taught**

Audience understanding will be evaluated through multiple-choice questions at the end of each section. Small practical projects are provided to test soft skills acquired, where reinforcement questions are also added in the subsections to keep students on the learning track.

### **1.8.4 Define the learning sequences**

For Students and researchers to be able to replicate the knowledge and the methodology developed in different settings, it is recommended that the course is followed through to the last section. Otherwise, course sectional skills can be acquired by completing the interested section.

The MOOC is divided into 5 sections (Table 4). Each section has a typical duration of 1 hour of videos. The MOOC participant/student will need about 1 week to complete a section, meaning approximately 4 hours of homework. In addition, each section has subsections (Figure 7) with a theoretical video with a typical duration of 6 minutes, and another 10-minute video for the practical videos. Although the duration of each video is different since they have had to be adapted to the content.

## MOOC

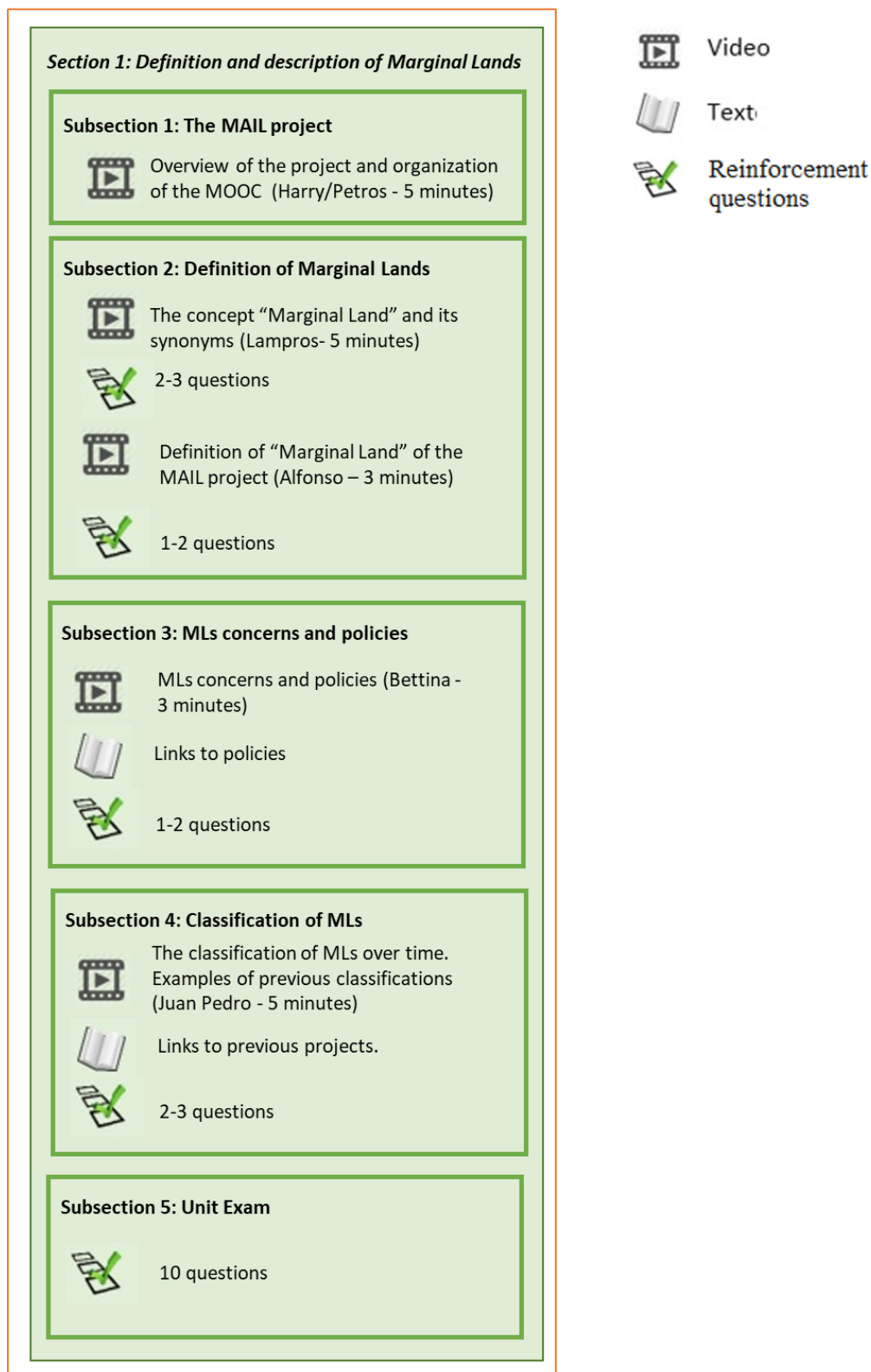


Figure 7: MOOC learning sequence. Source: Personal compilation.



## 1.9 Course implementation on the MOOC platform

The main objective of **MAIL** is to trigger the utilization of marginal lands as Carbon Sinks by activities related to forestry and agriculture. The project aims to detect and classify Marginal Lands, to deliver a web-based regional platform with data, methodologies, and applications which will be valuable for policymakers, stakeholders or researchers.

### 1.9.1 Section 1

Section 1 has to do with the definition and description of Marginal Lands. It includes five subsections with a corresponding presentation video each.

#### 1.9.1.1 Subsection 1

The first subsection takes place an overview of the **MAIL** project and organization of the MOOC.

##### Vid.ID 1.1 Overview of the project and organization of the MOOC

Description    The main objective of **MAIL** is to trigger the utilization of marginal lands as Carbon Sinks by activities related to forestry and agriculture.

Facilitator     Charalampos Georgiadis

Duration       00:03:05

#### 1.9.1.2 Subsection 2

The second subsection contains two presentation videos which introduce us to the concept “Marginal Lands”, interpret its synonyms and analyze its definition.

##### Vid.ID 1.2.1 The concept "Marginal Land" and its synonyms

Description    Introduction to the concept “Marginal Lands” and its synonyms

Facilitator     Lampros Papalampros

Duration       00:05:38



#### Vid.ID 1.2.2 Definition of “Marginal Land”

Description	Definition of ML within the scope of the <a href="#">MAIL</a> project
Facilitator	Bettina Felten
Duration	00:05:13

##### 1.9.1.3 Subsection 3

The third subsection informs us about the relations of Marginal Lands and environmental concerns and the policies that have to do with them.

#### Vid.ID 1.3 MLs concerns and policies

Description	Presentation of aspects of the relation between ML and environmental concerns and a brief description of the policy landscape related with marginality.
Facilitator	Alfonso Abad
Duration	00:03:57

##### 1.9.1.4 Subsection 4

The fourth subsection gives us examples of how Marginal Land classifications have been made in the past.

#### Vid.ID 1.4 The classification of MLs over time

Description	Discussion on how ML classifications have been made in the past, using some examples.
Facilitator	Juan Pedro
Duration	00:06:14



#### 1.9.1.5 Subsection 5

The fifth subsection introduce us to the European and Global datasets that were collected for the characterization of ML.

#### Vid.ID 1.5 Datasets used for characterization of ML

Description	Presentation of the European and Global datasets that were collected for the characterization of Marginal Lands
Facilitator	Lampros Papalampros
Duration	00:05:17

### 1.9.2 Section 2

This section is titled as “Identification and classification of marginal lands”. It provides an introduction to the overall approach and the tools used for the identification and classification of marginal lands. A description of the datasets used and how the spatial database is included. An introduction to the concepts of soft and hard layers and their processing is carried out. Furthermore, a description of the marginal land classification scheme is provided. The section is split to five subsections providing presentation videos each.

#### Vid.ID 2.0 General outline of the section

Description	Introduction to the overall approach and the tools used for the identification and classification of marginal lands.
Facilitator	Charalampos Georgiadis
Duration	00:01:10

#### 1.9.2.1 Subsection 1

This subsection includes two presentation videos that have to do with the presentation of the tools used for the identification and classification of Marginal Lands using an example - exercise through Qgis for the dataset’s selection and creation.



#### Vid.ID 2.1.1 Overall approach for the identification and classification of ML

Description Overall approach and presentation of the tools used for the identification and classification of ML and which datasets were used and how to create a database using opensource tools and software.

Facilitator Natalia Verde

Duration 00:08:32

#### Vid.ID 2.1.2 Qgis Example

Description The datasets that were used for the project and how they were selected.

Facilitator Natalia Verde

Duration 00:12:29

#### 1.9.2.2 Subsection 2

This subsection includes two presentation videos that have to do with the first phase of the proposed methodology and how to use available spatial data to identify hard layers of the methodology using Qgis in order to present urban areas delineation.

#### Vid.ID 2.2.1 Hard layers for identifying MLs

Description First phase of the methodology and how to use available spatial data to identify hard layers referring to areas with special characteristics that cannot be considered ML and are excluded from further analysis.

Facilitator Maria Tassopoulou

Duration 00:09:39

#### Vid.ID 2.2.2 Qgis Example

Description Delineate urban areas using the proposed methodology of the **MAIL** project.

Facilitator Maria Tassopoulou



Duration 00:22:37

### 1.9.2.3 Subsection 3

This subsection includes three presentation videos that have to do with the indicators and how they identify the degree of the land marginality and the review of the processing of the dataset presenting a practical example in Qgis.

#### Vid.ID 2.3.1 Soft constrains: Definition

Description Indicators that identify the degree of the land marginality.

Facilitator Jesús Torralba Pérez

Duration 00:06:18

#### Vid.ID 2.3.2 Soft constrains: Processing

Description A review of the processing of the dataset.

Facilitator Jesús Torralba Pérez

Duration 00:04:43

#### Vid.ID 2.3.3.1 Qgis example (Part 1)

Description Compilation of the steps to preprocess the marginality indicator layers. Practical exercise of pre-processing of 4 soft indicators in the free software QGIS. The indicators selected for the exercise are slope, soil depth, organic matter content (subsoil and topsoil) and soil texture (subsoil and topsoil). The objective of the exercise is for the student to learn a) the basic QGIS tools to preprocess the layers b) how to prepare the soft indicator layers to obtain a raster for each indicator with 3 values corresponding to 3 marginality ranges: high, low and potentially unsuitable land.

Facilitator Jesús Torralba Pérez

Duration 00:21:08



#### Vid.ID 2.3.3.2 Qgis example (Part 2)

We continue with the pre-processing with the QGIS processing modeler with the texture indicator.

**Description** In this case, as previously studied we use the layers with the Silt and Clay information, set the thresholds, and multiply by the corresponding weight. The process is performed both at subsoil and topsoil levels.

**Facilitator** Jesús Torralba Pérez

**Duration** 00:17:54

#### 1.9.2.4 Subsection 4

This subsection includes two presentation videos that have to do with analysis of the classification of ML according to their productivity. A practical example of that is given.

#### Vid.ID 2.4 The ML classification scheme in the MAIL project

**Description** Analyze the classification of ML according to their productivity.

**Facilitator** Jesús Torralba Pérez

**Duration** 00:05:53

### 1.9.3 Section 3

In this section we are exposed to the theory of biomass estimation from remote sensing data. The section contains five subsections that include presentation videos of theory and practical examples – exercises.

#### 1.9.3.1 Subsection 1

This subsection includes three presentation videos that deal with the remote sensing concept, remote sensing platforms and sensors and the theory of using remote sensing for biomass estimation.



#### Vid.ID 3.1.1 Remote sensing concept

Description Introduction to the remote sensing concept.

Facilitator Samuel Nyarko

Duration 00:04:36

#### Vid.ID 3.1.2 Remote sensing platforms and sensors

Description Presentation of remote sensing platforms and sensors.

Facilitator Samuel Nyarko

Duration 00:04:17

#### Vid.ID 3.1.3 Theory. Remote sensing biomass

Description Looking at theory of using remote sensing for biomass estimation.

Facilitator Samuel Nyarko

Duration 00:02:33

#### 1.9.3.2 Subsection 2

This subsection includes two presentation videos. In the first video the basic remote sensing features, functions and capabilities of the Sentinel 2 satellite are presented. In the second video are presented the features and differences between multispectral and hyperspectral optical remote sensors.

#### Vid.ID 3.2.1 Optical sensors: Sentinel 2

Description Introduction to optical sensors and Sentinel 2.

Facilitator Samuel Nyarko

Duration 00:05:07

#### Vid.ID 3.2.2 Optical remote sensors: Multi and Hyperspectral

Description Presentation of multispectral and hyperspectral optical remote sensors.



Facilitator Samuel Nyarko

Duration 00:02:50

#### 1.9.3.3 Subsection 3

This subsection includes two presentation videos that deal with: a) Radar sensors and Sentinel 1 and b) biomass estimation using data fusion from SAR and optical sensors.

##### Vid.ID 3.3.1 Radar sensors: Sentinel 1

Description Presentation of the Sentinel 1 satellite remote sensing features and capabilities.

Facilitator Samuel Nyarko

Duration 00:02:45

##### Vid.ID 3.3.2 Exercise. Biomass estimation with SAR/Optical data fusion

Description Presentation of ways in which biomass can be estimated using data fusion from SAR and Optical sensors.

Facilitator Samuel Nyarko

Duration 00:08:40

#### 1.9.4 Section 4

The section 4 provides the different kind of methods of tree biomass estimation, the destructive methods and the nondestructive methods, the indirect methods for carbon storage and accounting composed by biomass equations, predicting models, remote sensing, and GIS. Also, indirect methods for carbon sequestration estimation, using the IPCC guidelines are included. Furthermore, an exercise for carbon estimation will be explained for calculation of the carbon stock in above-ground and below-ground biomass pool in a forest plot of *Pinus nigra* Arn, using yield tables carbon species-specific content and allometric relationships is provided. The section is split to four subsections providing a presentation video each.



#### 1.9.4.1 Subsection 1

This subsection includes one presentation video that has to do with the different kind of methods of tree biomass estimation, the destructive methods, and the nondestructive methods.

##### Vid.ID 4.1 Direct Methods for carbon storage and accounting

Description Two different kinds of methods of tree biomass estimation: destructive methods and nondestructive methods

Facilitator Fernando Bezares Sanfelip

Duration 00:06:01

#### 1.9.4.2 Subsection 2

This subsection includes one presentation video that has to do with indirect methods for carbon storage and accounting composed by biomass equations, predicting models, remote sensing, and GIS.

##### Vid.ID 4.2 Indirect Methods for carbon storage and accounting

Description Indirect Methods for carbon storage and accounting composed by biomass equations, predicting models, remote sensing and GIS

Facilitator Fernando Bezares Sanfelip

Duration 00:06:32

#### 1.9.4.3 Subsection 3

This subsection includes one presentation video that has to do with Indirect methods for carbon sequestration estimation, using the IPCC guidelines.



#### Vid.ID 4.3 IPCC accounting rules

Description	Indirect methods for carbon sequestration estimation, using the IPCC guidelines that defined three tiers, three different approaches, and two methods for assessing and reporting GHG emissions.
Facilitator	Fernando Bezares Sanfelip
Duration	00:05:49

##### 1.9.4.4 Subsection 4

This subsection includes one presentation video of an exercise for carbon estimation will be explained for calculation of the carbon stock in above-ground and below-ground biomass pool in a forest plot in Castilla y Leon of *Pinus nigra* Arn, using yield tables carbon species-specific content and allometric relationships.

#### Vid.ID 4.4 Exercise

Description	Calculation of the carbon stock in above-ground and below-ground biomass pool in a forest plot of <i>Pinus nigra</i>
Facilitator	Fernando Bezares Sanfelip
Duration	00:09:36

### 1.9.5 Section 5

#### 1.9.5.1 Subsection 1

This subsection includes one presentation video that has to do with the presentation of the geoportal is the map of Europe along with the first three tools, called “exclude regions by land cover”, “exclude regions by productivity values” and “Productivity classification”.

#### Vid.ID 5.1 Map of Marginal Lands in Europe

Description	A presentation of the map of ML in Europe and three of the tools that the user can use in the geoportal of the <b>MAIL</b> project
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Facilitator      Michał Krupiński

Duration        00:07:17

#### 1.9.5.2 Subsection 2

This subsection includes one presentation video that has to do with the tool called “Carbon Calculator”.

##### Vid.ID 5.2 Carbon calculator

Description      The second group of tools is called “Decision Support System” and they are related to the efficient afforestation planning including tools to model and predict the carbon sequestration benefits coming from afforestation of marginal lands. This presentation video starts with the tool named “Carbon Calculator”.

Facilitator      Michał Krupiński

Duration        00:03:45

#### 1.9.5.3 Subsection 3

This subsection includes one presentation video which has to do with the second carbon related tool called “Carbon predictor”.

##### Vid.ID 5.3 Carbon predictor

Description      Through this tool we can model the amount of carbon would be sequestered from the atmosphere after one, two, 10, fifty years. As in previous tools we can mix up to 3 different tree species, define the percentage of each of them and the density of trees per hectare.

Facilitator      Michał Krupiński

Duration        00:05:31

#### 1.9.5.4 Subsection 4

This subsection includes one presentation video which deals with





#### Vid.ID 5.4 Afforestation cost calculator

Description	The last tool of the Decision Support System is called “Afforestation cost calculator”. Depending on input parameters, it helps to estimate what will be manual and mechanical cost of afforestation if we plan to have a forest with specific number of trees per ha.
Facilitator	Michał Krupiński
Duration	00:01:44

#### 1.9.5.5 Subsection 5

This subsection contains two presentation videos which deal with the tool from the Decision Support System called “Potential Suitable Species” and a tool used for multi-temporal analysis.

#### Vid.ID 5.5 Potential Suitable Species

Description	Presentation of the tool “Potential Suitable Species”. The purpose of the tool is to provide a general overview regarding CSC Groups and suggests Potential Suitable Species for afforestation of MLs in the AOI.
Facilitator	Lefteris Mystakidis
Duration	00:03:30

#### Vid.ID 5.6 Temporal Analysis

Description	Presentation of the functionality of multi-temporal analysis based on long archive of satellite observations. The tool is based on LandTrend algorithm.
Facilitator	Michał Krupiński
Duration	00:09:28



### 1.10 Quality review

Facilitators and UPV[X] management team will continue to provide updates and new improved techniques and fix any bugs that may arise to ensure continued stability and efficient service delivery in the life of the **MAIL** MOOC and also to be able to compete within the open-source knowledge sharing.

A user discussion forum is created so that the MOOC audience can voice their opinion when necessary. With the pool of student feedback, a course revision will be generated periodically. This will be done at the module level for quick and targeted feedback.

### 1.11 Conclusions

To sum up, it is therefore evident as indicated in the established reviewed literature in this document, that the relevance of Marginal lands to the contemporary green-biofuel driven envisage economy, coupled with the depth and scale of methodological developments of the **MAIL** project, could have only lived to its core mandate through knowledge sharing for wider scope adoption and integration worldwide. The **MAIL** MOOC was apt on this task and hence the need for a detailed outline and guidelines report, establishing the justification for the **MAIL** MOOC, guideline of the MOOC content development, the expected audience, and the chosen platforms for implementation.

## **2. ACCOMPANYING SOFTWARE SYSTEM**

The second part of the deliverable describes the software tool development process and the back-end architecture of a web-based software system for marginal land detection. A set of higher-level expert tools were developed and integrated into the geoportal of the MAIL project. A workflow for analysis of spatial/spectral change behaviour of MLs, and a tool to forecast short-term and long-term carbon budget and trends were integrated. Finally, a Decision Support System for ML management was developed and integrated into the web-based platform. The web-based platform was developed inside the Google earth engine software environment.

This document focuses on the theory concerning DBMS and the back-end architecture of the analytical procedures. The embedment of the developed tools into a web front end application are described in the deliverable 2.8.

### **2.1 Data**

This chapter briefly describes the main data sources used inside the software system. The **MAIL** project relied on a plethora of data sources to accomplish the goal of developing a Europe wide map of marginal lands. The data sources can be generally divided into two sets: satellite remote sensing data, and geographical (auxiliary) data.

#### **2.1.1 Satellite remote sensing data**

##### *2.1.1.1 Radar Data*

Synthetic Aperture Radar (SAR) is a form of radar that uses the motion of its antenna over the region of interest to capture the details of the target by sending an electromagnetic wave and receiving echoes backscattered from the area. It is a well-developed remote sensing technology with a wide range of applications for Earth and other planet surface mapping. The assortment of specialty includes topography, oceanography, glaciology, forestry but it can also assist in earthquake and volcano monitoring. Besides monitoring natural resources, it also has plenty of potential to assist in artificial surface or material detection and analysis. Being an active sensor, it also possesses the ability to operate on both day and night, and, in the majority of cases, regardless of meteorological conditions.

A typical SAR system is composed of a side-looking antenna mounted on a moving platform. The on-board instrument transmits an electromagnetic signal in form of a chirp and after some time registers the returning backscatter. The echoes are then placed within the image based on electromagnetic wave travelling time, thus allowing to distinguish object's location on the ground. Real aperture radar possesses an inherent poor azimuth resolution, and that is where the *synthetic* aperture helps. The signal processing technique of adding up the backscatters of the same scatterer on the ground from different pulses along the flight path allows to "synthetize" long antenna in azimuth direction, which determines the spatial resolution in azimuth direction. The resolution in range direction is determined by the transmitted chirp bandwidth. Another important SAR feature is its wavelength. The system operates in the microwave range of the electromagnetic spectrum, meaning that the typical wavelength can be anywhere between few centimeters and several meters. Consequently, the wave can pierce the atmosphere unattenuated under normal circumstances.

Another useful SAR feature is the ability to send and receive signals in different linear polarization directions. Any combination(s) of HH, HV, VH and VV, where H stands for horizontal and V for vertical, while the first symbol is for send and the second for receive, can be used by particular system. Such feature allows to distinguish between different types of structures illuminated on the ground, as various shapes of objects interact differently based on incoming signal polarization.

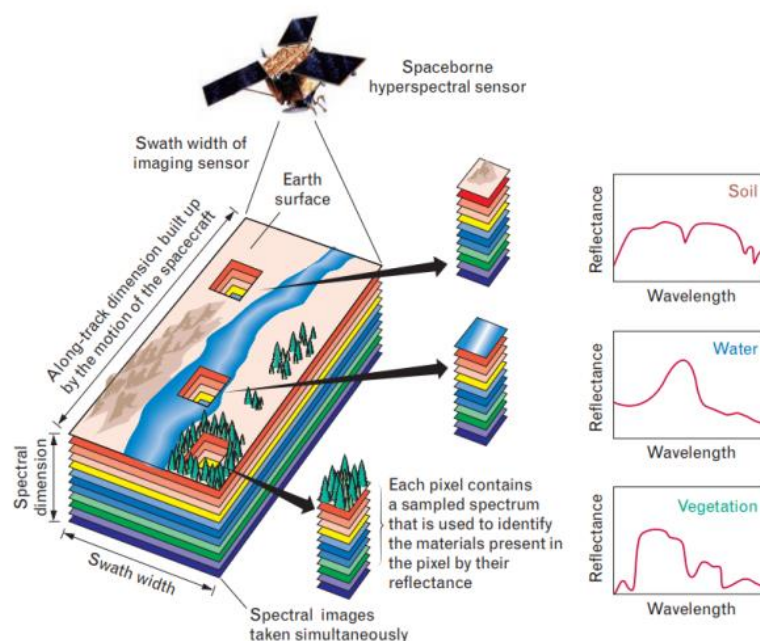
Every SAR image element is complex in nature, as it contains both amplitude and phase. Interferometric SAR (InSAR) technique employs the phase part of two or more SAR images of the same location taken from the same viewing geometry to form an interferogram which allows to determine target location in three dimensions. Based on wavelength, such technique can measure surface elevation even up to millimeter precision, therefore, making it a powerful tool in science. Moreover, combining multiple such observations gives an impressive 4D representation. Finally, as it will be revealed later, interferogram quality measure, namely coherence, can be successfully used to estimate biomass on its own.

The amplitude part of a complex SAR pixel provides the measure of surface reflectivity properties, which depends on the angle, the dielectric properties and the surface roughness of the object. The fact that multiple scatterers are illuminated in a single resolution cell creates the so-called speckle effect, which makes SAR images look

granular. As a consequence, a variety of SAR image filtering options are employed to remove this effect when processing SAR images.

#### 2.1.1.2 Optical Data

Optical satellite imagery is a passive form of remote sensing, where the measurements are made thanks to an external source of illumination, in this case the sun. The sun emits EM waves in all wavelengths, gets reflected from objects on Earth, and in the case of optical or multispectral imagery, the visible wavelengths (VIS) (380 nm to 740 nm), near-infrared radiation (NIR) (750 nm to 1400 nm) and short-wave infrared radiation (SWIR) (1400 nm to 3000 nm) are captured to form images. However, not all wavelengths are completely transmitted. Due to absorptions in the atmosphere, some wavelengths are completely absorbed or partially attenuated when entering the Earth. At the surface, the received waves are either absorbed, transmitted, or partially absorbed and re-emitted at another wavelength. And then when they are reflected towards the satellite, they once again undergo attenuation in the atmosphere. The relationship between the incident and reflected radiation is a function of the incident angle, but primarily on the chemical composition of the object. This property is extremely useful, and it is what leads to objects to have distinct spectral signatures that makes distinct identification of the object possible (Shaw y Burke, 2003). This is the main principle behind optical remote sensing (Figure 8).



**Figure 8: Overview of multispectral satellite remote sensing. Source:** (Shaw y Burke, 2003)

Sentinel-2 is a satellite mission launched by ESA under the Copernicus Programme, while using multispectral sensor as its main instrument. The mission of the satellite is to provide data for land-use/land-cover (LULC) and environmental monitoring, disaster and risk monitoring, urban and terrestrial mapping etc. amongst a plethora of other applications. It consists of a constellation of two satellites, Sentinel-2A and Sentinel-2B, which orbit the Earth in the same sun synchronous orbit at 786 km altitude. The two satellites are arranged in the orbit 180° apart to improve the revisit time from 10 days for one satellite to 5 days at the equator, and higher revisits at higher latitudes. The local time of descending node is 10:30 am enabling the satellite sufficient illumination while minimizing cloud coverage. The main instrument payload is called the Multispectral Instrument (MSI), with a push broom configuration and consisting of thirteen spectral bands in the VIS, NIR and SWIR ranges. The resolution ranges from 10 m for the VIS wavelengths to 60 m for the cirrus and water-vapor bands, which are used for atmospheric corrections. The properties of the different bands, names and uses are provided in Table 5. It is important to note the presence of several channels in the red-edge bands, making Sentinel-2 the first civil use satellite to do so, providing very key information about vegetation state (Clevers y Gitelson, 2013).

**Table 5: Sentinel-2 bands**

Band Nr	Band Name	Central Wavelength [nm]	Bandwidth [nm]	Spatial Res. [m]	Purpose Example
B1	Aerosol	443	20	60	Atmospheric correction
B2	Blue	490	65	10	Land cover classification
B3	Green	560	35	10	Land cover classification
B4	Red	665	30	10	Land cover classification
B5	Red-edge 1	705	15	20	Vegetation classification
B6	Red-edge 2	740	15	20	Vegetation classification
B7	Red-edge 3	783	20	20	Vegetation classification
B8	NIR-wide	842	115	10	Chlorophyll monitoring
B8 b	NIR-narrow	865	20	20	Vegetation classification
B9	Cirrus	945	20	60	Cirrus cloud detection
B10	Water Vapor	1375	30	60	Atmospheric correction
B11	SWIR-1	1610	90	20	Lignin monitoring
B12	SWIR-2	2190	180	20	Veg. Health monitoring

The Sentinel-2 provides two levels of data as its main user products. The first is the Level-1C product which is the top-of-atmosphere reflectances with radiometric and



geometric corrections applied, whereas the second product Level-2A contains bottom-of-atmosphere reflectances, which has additionally atmospheric corrections as well (Drusch et al., 2012)).

#### *2.1.1.3 Auxiliary data*

The auxiliary data consist of a wide range of geographical datasets which were gathered during the project and used as inputs for the classification and mapping of marginal lands in Europe. The entire list auxiliary data is given in Table 6. Deliverables 2.3 describes each dataset in detail.



**Table 6: Auxiliary data used in MAIL project**

Group	Data	Spatial Resolution / MMU	Coverage	Product Date	Values Range
Climate	TerraClimate: Monthly Climate and Climatic Water Balance for Global Terrestrial Surfaces	~4.5km	global	1958-2018	PET: 80-239, PC: 0-1559
LULC	Coastline EU	NA	European	NA	thematic
	CORINE LC	25ha	EEA39	2018	thematic
	CORINE LC change	5ha	EEA39	2018	thematic
	Global Forest Change	30m	global	2000-2018	thematic
	Imperviousness Classified Change (IMCC)	20m	European	2012-2015	thematic
	Imperviousness Density (IMD) HRL	20m	European	2015	thematic
	JRC Global Surface Water	30m	global	1984-2019	0-100%
	Nationally designated areas (CDDA)	NA	European	2019	thematic
	Natura2000	NA	EEA33	2018	thematic
	S2GLC	10m-60m	European	2017	thematic
	TanDEM-X Global Forest map	50m	global	2011-2015	thematic
	Tree Cover Density (TCD)	20m	European	2015	thematic
	Tree Cover Density Change (TCDC)	20m	European	2012-2015	1-100%
Productivity	Organic carbon content (topsoil & subsoil)	1km	European	2013	0-39.5
	Soil biomass productivity of forest areas	1km	EU27	2016	0.17-10
	Soil biomass productivity of grasslands and pastures	1km	EU27	2016	0-10
Soil	Total available water content from PTF	1km	European	2013	NA
	Clay content (topsoil & subsoil)	1km	European	2013	0-76
	Depth available to roots	1km	European	2013	0-150





	Sand content (topsoil & subsoil)	1km	European	2013	0-90
	Silt content (topsoil & subsoil)	1km	European	2013	0-71
	Soil pH in Europe	5km	EU25 (Romania & Bulgaria are not included,)+Norway, Switzerland, Croatia, Albania	2009	0.6-8.8
	Volume of stones	NA	EU27	2008	0%-20%
	WRB-FULL. Full soil code of the STU from the World Reference Base (WRB) for Soil Resources	NA	EU27	2008	thematic
	WISE derived soil property estimates	~10km	global	2015	sodicity: ESP [-9-98] , nitrogen: TOTN [-9-23.48] , gypsum: GYPS [-9-684] , CEC: CECs [-9-128], soil types
Sustainability	Soil erosion by water (RUSLE2015)	100m	EU28	2015	0-325
	TerraClimate: Monthly Climate and Climatic Water Balance for Global Terrestrial Surfaces	~4.5km	global	1958-2018	PET: 80-239, PC: 0-1559
	WISE derived soil property estimates	~10km	global	2015	sodicity: ESP [-9-98] , nitrogen: TOTN [-9-23.48] , gypsum: GYPS [-9-684] , CEC: CECs [-9-128], soil types
	JRC Global Surface Water	30m	global	1984-2019	0-100%
Terrain	EU-DEM	25m	European	2011	NA



## 2.2 Software ecosystem for spatial analysis

### 2.3 GIS software

In the commercial sector, best-known manufacturers include Autodesk (Topobase and Map3D), Bentley Systems (MicroStation), ESRI (ArcGIS), Intergraph (GeoMedia), Manifold System, Pitney Bowes (MapInfo and pbEncom), Supergeo (SuperGIS), Disy Informationssysteme GmbH (Cadenza) and Smallworld. These manufacturers usually offer a complete range of products with systems in various stages of expansion. Authorities and the military mostly use specially created, adapted (e.g. ESRI (ArcGIS), Pitney Bowes (MapInfo), CAIGOS (CAIGOS-GIS), GEOgraFIS, POLYGIS), or open source software products.

The best-known open-source GIS are GRASS GIS and QGIS, both projects of the Open Source Geospatial Foundation, as well as OpenJUMP and DIVA-GIS. There are numerous other systems or GIS tools such as SAGA GIS, FWTools, GeoTools or OpenLayers.

In the area of online GIS, Google Maps dominates with Google Earth as desktop access software, Bing Maps, HERE, Yandex.Maps and OpenStreetMap as open-source projects.

R is a language and environment for statistical computing and graphics. R provides a wide variety of statistical and graphical techniques and is highly extensible. Hundreds of R packages ranging from ecology and earth observation, hydrology and soil science, to transportation and demography are related to spatial data analysis. These packages support various stages of spatial analysis, including data preparation, visualization, modeling, or communicating the results. One common feature of most R spatial packages is that they are built upon some of the main representations of spatial data in R, available in key geographic R packages such as:

- sf, which replaces sp
- terra, which aims to replace raster
- stars

Google Earth Engine (hereafter GEE) is a computing platform that allows users to run geospatial analysis on Google's infrastructure. GEE is available for free for scientific and academic use. GEE has a large database of several freely available satellite datasets,

climate and higher level processed spatial datasets, stored in cloud. The database can be accessed, analysed and processed using an online software platform, and the processing is also performed on the cloud (Gorelick et al., 2017).

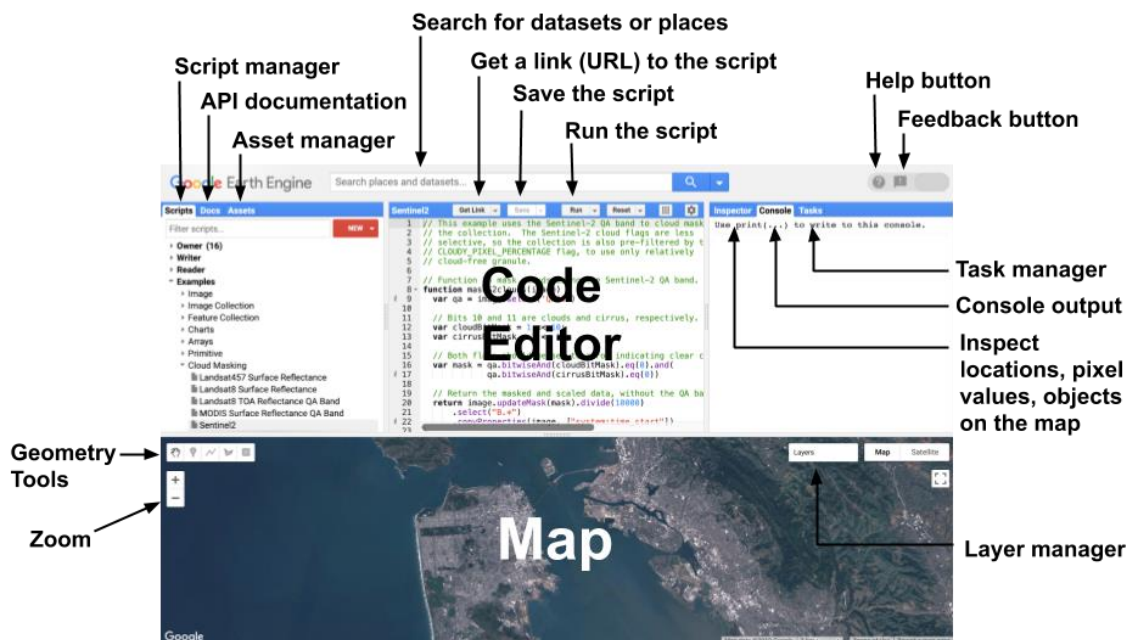


Figure 9: Overview of Google Earth Engine API. Source: (Google, 2021b)

### 2.3.1 DBMS Software

Data Base Management System (DBMS) is the system software of a data bank system (DBS) including the data stored and a data bank communication link. A DBMS has the following functionalities:

- Integrated data retention.
- Language. Data retrieval, Data Manipulation Language (DML), Data Bank Management (Data Definition Language, DDL), Control I (Data Control Language, DCL).
- Catalog. Description of tables and their columns (file type, length, etc.).
- User views. For different classes of users are different views (views), the best cut from
- Consistency control. The consistency checks, as well as the integrity assurance, are supervised by the correction of the correctness of the data bank and the correct execution of the undertakings.



- Integrated security and data acquisition control. Due to the regulation of regulations, unauthorized access to the data stored in the data bank has been recorded.

### 2.3.2 GEE Data model

The two most fundamental geographic data structures in Earth Engine are Image and Feature corresponding to raster and vector data types, respectively. Images are composed of bands and a dictionary of properties. Features are composed of a Geometry and a dictionary of properties. A stack of images (e.g., an image time series) is handled by an ImageCollection. A collection of features is handled by a FeatureCollection. Other fundamental data structures in Earth Engine include Dictionary, List, Array, Date, Number and String. It is important to remember that these are all server-side objects and are not manipulated the same way as client-side JavaScript objects

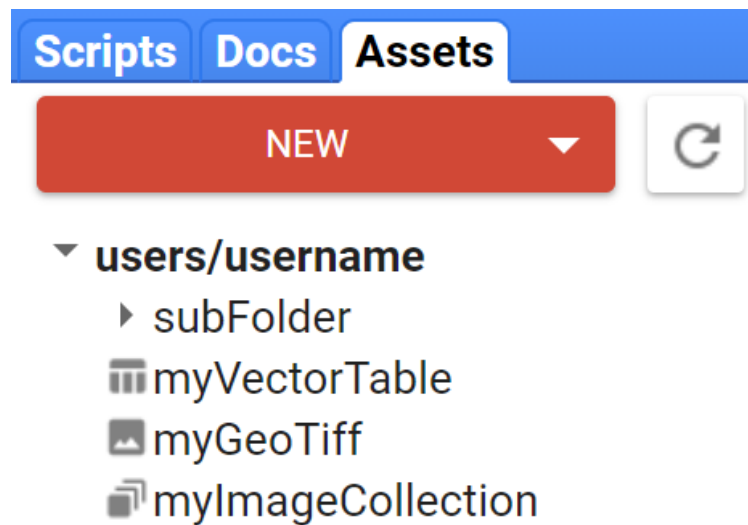
## 2.4 Software tool development

### 2.4.1 DBMS development

This chapter describes the development of the data base which stores all relevant inputs, intermediate and final products. The DBMS exists in the form of an asset repository on Google Earth Engine and all assets are open access. In addition, the project leverages several datasets from the GEE data catalogue. The chapter ends with a practical example on how to query data stored as an asset in the [MAIL](#) repository.

#### 2.4.1.1 Data storage

In the framework of the [MAIL](#) project the database selected to store the data was the Google Assets (Assets) platform. Google Assets is a database or data storage framework imbedded in the Google Earth Engine (GEE). This framework is designed to work interconnected with the Google Earth Engine API. Therefore, in order to access the assets, it is mandatory to have a google account linked with GEE. For each user account associated with GEE, Google Assets allow a maximum of 250 GB distributed in a maximum of 10,000 files.



**Figure 10: Example of GEE Asset repository. Source:** (Google, 2021a)


Once in the GEE platform, Assets will appear accessible in the label “Assets”. Here the platform allows to manually introduce different types of information, mainly: **Image information (raster) or Table information (vector)**. The data formats accepted for the data base are GeoTIFF or TFRecord format for the images and Shapefile or csv for the Vector data. Additionally, Assets allows the creation of directories and Image collections for a better data arrangement.

In order to upload an asset, the user must click on new and select the type of data to be inserted. Then, explore the data to be inserted in the local disk, name the asset and specify the data properties if necessary. Moreover, advanced processing options are offered to understand how GEE will work with our data and, therefore select the best options (generally pyramiding policy) according to the data to be imported. It is important to note that Assets restricts its uploads size to a maximum of uploads exceeding 10GB.

**Figure 11: Example of file ingestion into Asset repository.**

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**Sentinel-2 MSI: MultiSpectral Instrument, Level-2A**



**DESCRIPTION** BANDS IMAGE PROPERTIES TERMS OF USE

Sentinel-2 is a wide-swath, high-resolution, multi-spectral imaging mission supporting Copernicus Land Monitoring studies, including the monitoring of vegetation, soil and water cover, as well as observation of inland waterways and coastal areas.

The Sentinel-2 L2 data are downloaded from scihub. They were computed by running sen2cor. WARNING: ESA did not produce L2 data for all L1 assets, and earlier L2 coverage is not global.

The assets contain 12 UINT16 spectral bands representing SR scaled by 10000 (unlike in L1 data, there is no B10). There are also several more L2-specific bands (see band list for details). See the [Sentinel-2 User Handbook](#) for details. In addition, three QA bands are present where one (QA60) is a bitmask band with cloud mask information. For more details, see the [full explanation of how cloud masks are computed](#).

EE asset ids for Sentinel-2 L2 assets have the following format: COPENICUS/S2\_SR/20151128T002653\_20151128T102149\_T56MNN. Here the first numeric part represents the sensing date and time, the second numeric part represents the product generation date and time, and the final 6-character string is a unique granule identifier indicating its UTM grid reference (see [MGRS](#)).

Clouds can be removed by using [COPENICUS/S2\\_CLOUD\\_PROBABILITY](#). See [this tutorial](#) explaining how to apply the cloud mask.

For more details on Sentinel-2 radiometric resolution, see [this page](#).

**Dataset Availability**  
2017-03-28T00:00:00 - 2021-10-23T00:00:00

**Dataset Provider**  
[European Union/ESA/Copernicus](#)

**Collection Snippet**  
`ee.ImageCollection("COPENICUS/S2_SR")`  
[See example](#)

**Tags**  
eu esa copernicus sentinel msi sr reflectance

[CLOSE](#) [IMPORT](#)

**Figure 12: Data description and metadata for an asset**

Typically, the key elements to consult in the Metadata table are, the dataset availability, the bands/features technical descriptions and the importing options: both the snippet with the Asset id and the import button.

#### 2.4.1.1.1 Google Earth Engine Data Catalogue

Next to the data storage, GEE curates an extensive data catalogue. It includes the entire MODIS, Landsat, and Sentinel Archives, most used land cover classifications, as well as environmental data such as topography and climate.

#### 2.4.1.1.2 Database query

The database can be operated in the API in two different ways, by importing files from your Assets or requesting data from other user Assets into a workflow, or exporting results (data) or assets.

To import the asset in the GEE API, copy the import snippet code or click on the import button, this will automatically add the import snippet code in your code editor.

Google Assets allows as well to share data between users. To share an asset you can hover over the asset name and click on the share icon. A menu will be displayed allowing



you to configure read or write access for individuals, Google Groups and Earth Engine Apps. To access a public asset that it is neither stored in our repository nor in the GEE database, we use the “require()” function. Require() allows us to call a public asset in to our code editor just by introducing the asset id.

Additionally, all the assets or results from your analysis can be exported using the Export functions. There are 4 main export functions according to the type of data to be exported, Export.image (for images), Export.table (for vector data with or without geometries), Export.map (images exported as a rectangular pyramid of map tiles), Export.video( ImageCollection as a video). Moreover, GEE offers three different destinations to download the information: toDrive(), toCloudStorage() and toAsset().

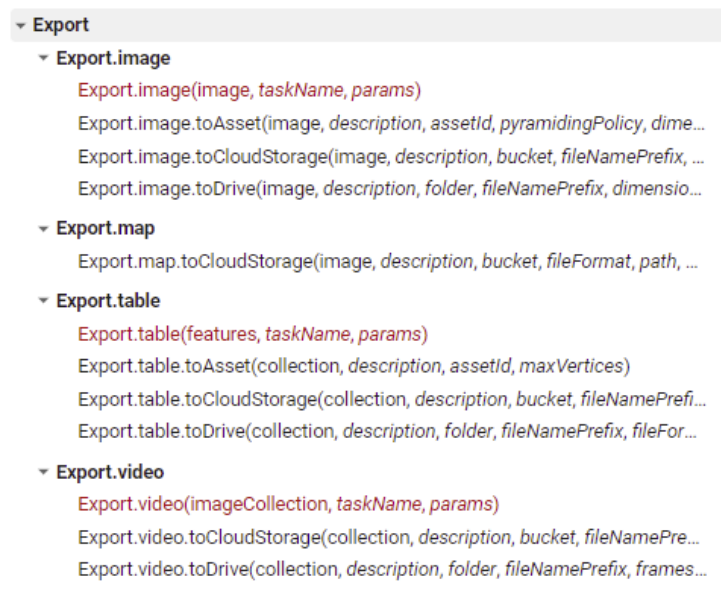


Figure 13: Exporting options offered in the GEE Assets.

## 2.5 GIS/Remote Sensing framework development

This chapter describes the back-end infrastructure of the marginal lands online web app. The web app encompasses all major methodological achievements developed during the lifetime of [MAIL](#) project. The core of the app is the marginal land identification workflow, the methodologies of which is extensively described in deliverable 2.3 The back-end itself is structured in scripts organized in several folders.





### 2.5.1 Task 2.3 Marginal Land identification

The marginal identification methodology starts by integrating the layers that will be used for the generation of hard layer in the JS object **hard\_layers\_list** and the classification of the hard layer into marginality classes using the soft layers stored in the **soft\_layers\_list** object and the default weights for the classification in **sl\_groups**.

Four main functions are used to generate the base marginal layer:

- **gen\_mask()**: selects the hard layers from the **hard\_layers\_list** and mask out the layers selected by the user in the checkboxes. It returns a mask from the **hardlayers** list. The result of this function applied to default values is stored in the variable **m**.
- **gen\_weights()**: assigns a soft-layer with a weight, if default, it will do it for the **default\_weights** object. It normalizes weights and passes the value as a vector/array. The result of this function applied with default values is stored in the variable **w**.
- **gen\_soft\_layers()**: creates a multiband image from the **soft\_layers\_list** in the variable **s**.
- **gen\_classes()**: reclassifies an image in three classes. The inputs are 3 thresholds. It is used to reclassify the productivity ranks in 3 classes.

The marginal lands productivity, var **mls**, (default values) is obtained by multiplying the soft layer multiband image (**s**) by the array of weights (one array for each band) and then “reducing” the band to a single one band image (sum function) and represent the values in percentages. Next, the **mls** layer is classified in 3 classes using **gen\_classes()** using 30% and 50% as productivity thresholds. The output layer is called **classes**. Finally, both **mls** and **classes** are masked using the mask from **gen\_mask()**, **m**.

The outputs provided by the functions listed above can be modified in the graphic user interface, in the following menus:

- Inside the menu “Exclude areas by land cover”, to operate and define the hard layer. The function **updateMasks()** evaluates the value of the 65 checkboxes and updates the values passed to the function **gen\_mask()**
- The menu “Exclude areas by productivity values” allows the user to remove marginal land areas according to their productivity values. To do so, the user introduces in the ui.TextBoxs (**excl\_v1** and **excl\_v2**) the exclusion values, which



are passed to the **eapply\_button** (ui.Button) where a locally defined function mask the **mls** applying the thresholds.

- The “Factor importance selection” panel allows the user to define the thresholds and weights for each of the soft layers. The user can introduce the factor importance as a general weight for the factor groups (terrain and soil, Sustainability and Productivity) or define the weights for all the soft layers within each group. Every time the user changes the weights the importance of each factor is reflected (function **wChange()**). The apply button triggers a locally defined function that iterates over the soft layers groups and soft layers and obtains the user inputted weights and passes them to **gen\_weights()**, **gen\_softlayers()**, obtaining a new value for **w** and **s** respectively. Finally, it redefines the **mls** productivity layer applying a spatial overlay.
- The slider “Marginal Land classes” displays a tool that allows the user to classify the productivity values in 3 classes. By means of a ui.Select object (**cls\_select**), the user can select 4 different ways of classifying the MLs:
  - By equal magnitude
  - Using the 25<sup>th</sup> and 75<sup>th</sup> percentiles
  - Using the 33<sup>rd</sup> and 66<sup>th</sup> percentiles
  - Custom classes

Next, a study area must be selected to perform the classification of the MLs. The study areas are defined using either a NUT level 2 area defined by GAUL level 1 layer or by a user defined area. Both options are controlled by a ui.Select object (**cls\_region**), that calls the function **collectGeometry()**<sup>3</sup>. This function takes the GAUL level 1 ee.Feature() and adds it to Map.drawingTool.layers().

Once the study area and the thresholds are defined, the user must click on “apply button” to trigger **changeClsMethod()**. This function selects the value obtained by the **cls\_region** and **cls\_select** widgets and passes them to **gen\_classes()** and clips them to the selected area.

## 2.5.2 Augmenting Marginal land precision

The tool offers a way to increment the identification of MLs in a local scale, since the European MLs identification might not be adapted to local conditions. In this sense, the

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<sup>3</sup> global function applied for user defined areas.

enhanced marginal land identification methodology presented is time sensitive, meaning that the user can select a time range of at least 2 years to generate a classification.

The methodology first generates a European base map from Sentinel 2 and Sentinel 1 indicators for 2017. The indicators selected for S2 are NDTI, NDWI and NDVI for September, May and July. In addition, a harmonic model for NDVI trends was computed to provide information about amplitude and phase. On the other hand, the Sentinel 1 indicators where the VV and VH bands for April, June and October. In GEE, the Generation of the training image contained the following workflow steps

#### Sentinel-2 variables

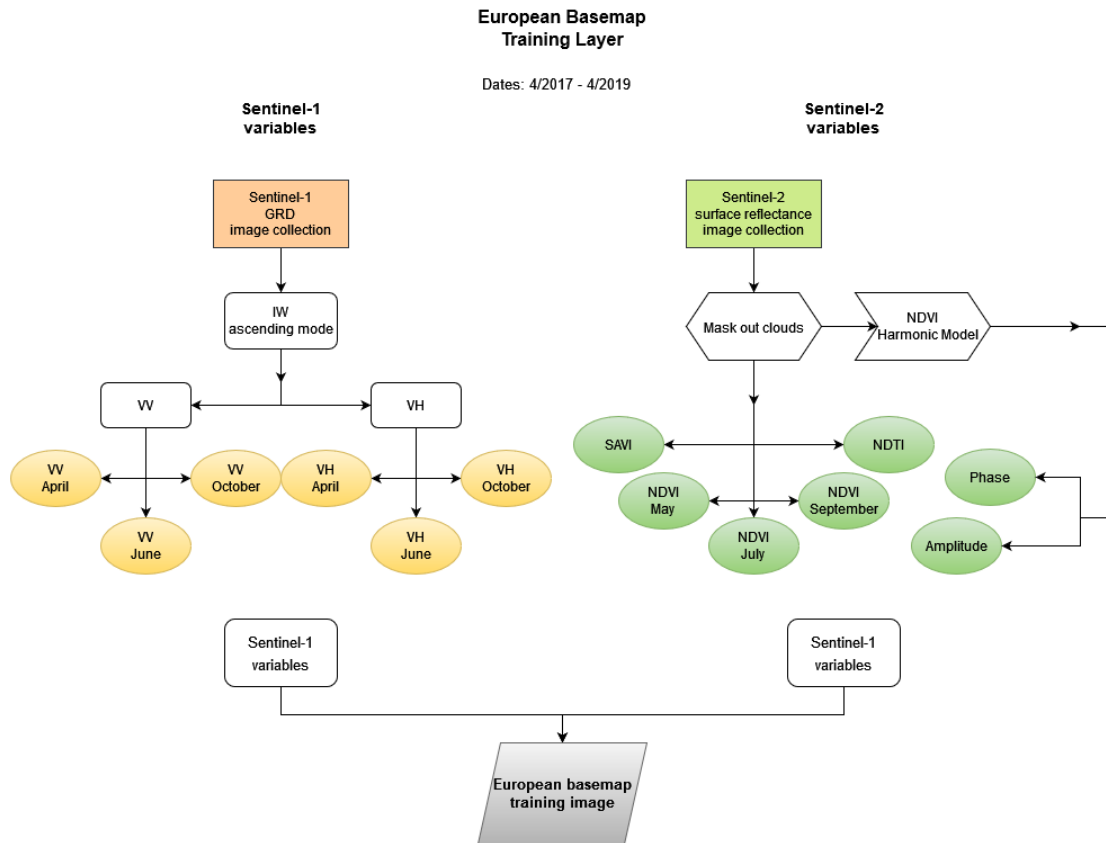
- Mask out clouds
- Compute Phase and Amplitude parameters from the Harmonic Model of NDVI utilizing Time Series Analysis for training dates
- Computation of mean NDVI for May, July and September
- Computation of mean SAVI, NDTI

#### Sentinel-1 variables

- Filter IW mode, ascending pass
- Compute mean VV values for April, June and October
- Compute mean VH values for April, June and October

#### Export pan European layer

- Add S2 variables to an image as bands
- Add S1 variables to an image as bands
- Concatenate S2 variables and S1 variables in one image per country
- Create a European mosaic of all countries (100 m resolution)



**Figure 14: Workflow of European training image generation for augmenting ML precision.**

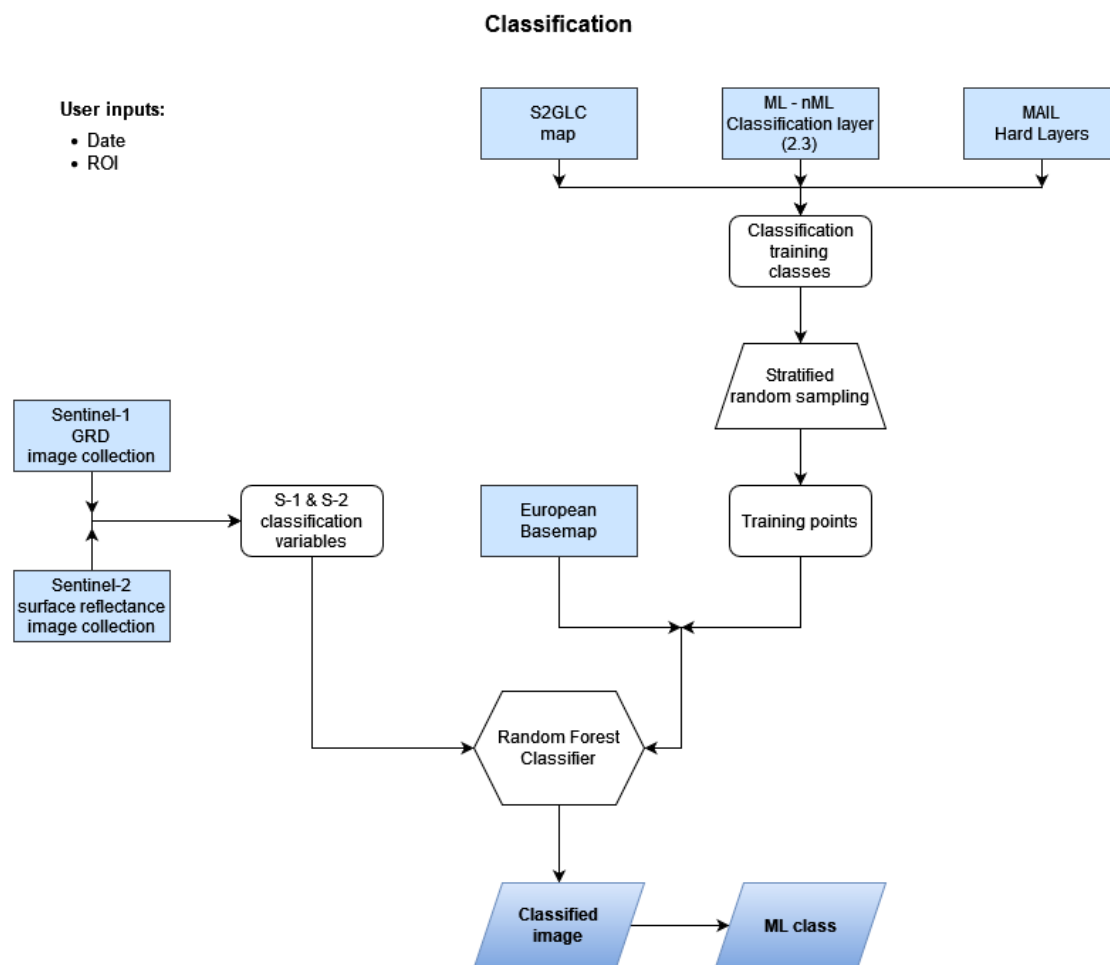
**Source:** (Krupiński and Spanos, 2021)

Once the base map is generated, training applying a stratified sampling strategy in 3 layers to obtain information about the landcover classes and the MLs distribution. The layers used to obtain info about landcover are the Sentinel 2 Global Land Cover (S2GLC) and the **MAIL** Hard Layer masks. On the other hand, the MLs distribution was obtained using the result of the Task 2.3 Marginal land identification layer (MLnML) which was reclassified to 0-1 indicating marginal and not marginal. Parallely, the same process designed to obtain the European base layer is run with the user defined dates. Synthetically, the classification workflow includes the following steps:

- Compute S2 and S1 classification variables for a (user-) specified region and time range of interest (at least 2)
- Create training layer with desired classes:
  - 'forests': ee.Image('users/cbk/HardLayers/forest2018\_10'),
  - 'croplands': ee.Image('users/cbk/HardLayers/crops01'),
  - 'impervious': ee.Image('users/cbk/HardLayers/IMPERVIOUS\_10'),

- 'water bodies': s2glc.expression('b(0) == 162 ? 1 : 0'),
- 'ML': MLnML.where(MLnML.gt(1),1).updateMask(MLnML)
- Stratified random sampling per class (1000 points per class)
- Extraction of values from pre-developed European training image
- Apply random forest classifier (1000 trees) to the (user-) specified region using as training the pre-developed European image

Finally, a machine Learning (Random Forest) model is run to compute the classification, as a result a landcover map is obtained from which the marginal land is extracted.



**Figure 15: Classification workflow for augmenting ML precision.** Source: (Krupiński and Spanos, 2021)

### 2.5.3 Forecast of short-term trends (carbon calculator)

The Carbon Calculator Tools aim is to provide a Carbon estimation for the aboveground biomass components of a given area representing a forest plot of known density (number

of trees per hectare) and mean breast height diameter (in cm). Alternatively, it can be used to assess the Carbon fixed by a reforestation when a given diameter is reached. This tool performs the calculation for a mixture of maximum 3 species.

The carbon estimation is based on a compendium of generalized diameter-dependant aboveground biomass equations proposed by (Forrester et al., 2017)<sup>4</sup>. The equations were stored in a separated script **biomassEquations.js** and were extracted and rewritten in a JavaScript object (**biomass**) which holds, for the keys, the scientific name of the species and in the values a function that contains the biomass equation.

```
var biomass = {  
  abies_alba : {  
    equation :function(dbh){  
      var dbh_ee = ee.Number(dbh);  
      var ly = ee.Number(-2.3958).add(ee.Number(2.4497).multiply(dbh_ee.log()));  
      var abg = ly.exp();  
      return abg ;  
    }  
  }  
}
```

**Figure 16: Example equation for estimation of aboveground biomass for the European Silver Fir (*Abies alba* Mill.)**

The species are limited by the biomass equations availability. To select the species biomass equations an ui.Select widget calls the “**biomass\_eq**” object and extracts the equations by keys. The input for the equations, percentage of mixture of each species, forest plot density (trees/ha) and diameter at breast height (DBH) are introduced using a ui. Textbox widget.

All these inputs are a passed into the function **calculateCarbon()**. This function first, performs an input data quality check, where it ensures that:

- There are 3 species selected, if only two species are desired, then select the same species in one slot and add 0% for one of them
- The aggregation of mixture percentage does not exceed 100%

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<sup>4</sup> biomass functions extracted from forrester et al 2017

[https://www.waldwachstum.wzw.tum.de/fileadmin/publications/forrester\\_etal\\_2017.pdf](https://www.waldwachstum.wzw.tum.de/fileadmin/publications/forrester_etal_2017.pdf)

Forrester, D. I., Tachauer, I. H. H., Annighoefer, P., Barbeito, I., Pretzsch, H., Ruiz-Peinado, R., ... & Sileshi, G. W. (2017). Generalized biomass and leaf area allometric equations for European tree species incorporating stand structure, tree age and climate. *Forest Ecology and Management*, 396, 160-175.



- The input slots are not empty, that is the slots for DBH, mixture percentage or plot density.

Once the inputs are verified, then are passed into the biomass equations stored to obtain the biomass for each species. Then the plot biomass is estimated by a weighted aggregation of all the biomass using the mixture percentage as weights and then multiplying the result by the plot density to get the biomass for one hectare. To obtain the carbon biomass value is multiplied by 0.5. This result is stored in the variable **carbon**.

Then the function calculates the carbon stored for each MLs class inside a user defined area. For this, first it checks if there are geometries drawn in the canvas by using the following expression: `Map.drawingTools.layers().length() < 0`. If so, it creates a mask for each marginal value using “mask value” function which asks for an image (the marginal land classification), the class value and the user defined geometry. Once the masks are defined, the area of each MLs class is calculated using `ee.reduceRegion()` over an `ee.Image.pixelArea()` masked with each mask and aggregating the pixel area with `ee.Reduce.sum()`. Once the area in hectares is calculated for each MLs class it is multiplied by the carbon in each class, to obtain the carbon sequestered in each MLs class. Finally, the results are printed using a `ui.Textbox()`.

#### **2.5.4 Modelling spatial/spectral change behaviour of MLs from satellite time series data (carbon predictor)**

The carbon predictor tool main objective is to estimate the future carbon stock in a reforested plot. It can be applied both to a user delimited area or to a general area. If a user defined area is used then a diameter at breast height (hereafter as DBH) increment model is applied, if not mean species increment coefficient is estimated. The tool uses one DBH increment model for each species that is parameterized using forest inventory, climatic and topographic data. Therefore, these models are area sensitive and the DBH increment will change depending on the user delimited area. The DBH increment models were extracted from (Schelhaas et al., 2018)<sup>5</sup>. As it was done with the biomass

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<sup>5</sup>Schelhaas, MJ., Hengeveld, G.M., Heidema, N. et al. Species-specific, pan-European diameter increment models based on data of 2.3 million trees. *For. Ecosyst.* 5, 21 (2018). <https://doi.org/10.1186/s40663-018-0133-3>

equations, each diameter increment model was stored in a JavaScript object (**dbhIncrement**) shown in the Figure 17.

```
var dbhIncrement = {  
  abies_alba : {  
    equation : function(density, region, b1_nobasal_clipped, b2_nobasal_clipped, years, dbh_evolution) {  
      var dbh_ee = ee.Number(ee.List(dbh_evolution).get(-1)).multiply(10.0); //convert to mm  
  
      var ba = ee.Number(Math.PI).multiply(((dbh_ee.divide(1000.0)).divide(2.0)).pow(2.0)).multiply(density);  
      var b1_abies_spp = b1_nobasal_clipped.add(ee.Number(-0.061).multiply(ba.log()));  
      var b2_abies_spp = b2_nobasal_clipped.add(ee.Number(0.00912).multiply(ba.log()));  
      var inc_dbh = (b1_abies_spp.multiply(dbh_ee)).add(b2_abies_spp.multiply(dbh_ee).multiply(dbh_ee.log()));  
  
      var mask = inc_dbh.lt(0);  
      var inc_dbh_filtered = mask.multiply(0).add(inc_dbh.multiply(mask.not()));  
  
      var mean_inc_dbh = inc_dbh_filtered.reduceRegion({  
        reducer: ee.Reducer.mean(),  
        geometry: region,  
        scale: 1000,  
        maxPixels: 1e13  
      });  
    }  
  }  
  return ee.List(dbh_evolution).add((dbh_ee.add(ee.Number(mean_inc_dbh.get('b1')))).divide(10.0)); //returns new dbh in cm added to
```

**Figure 17: Example equation for estimation the DBH growth for the European Silver Fir (*Abies alba* Mill.)**

In the carbon predictor panel, the user can select three different species for the prediction using ui.Select widgets that will call `Object.keys(biomass_eq)` to obtain the list of species considered in the biomass equations of the carbon cost calculator. Additionally, the user must indicate the density of the plantation to run the simulation and the percentage of mixture of the species in the plantations. Both the percentages of mixture and the planation density is specified using ui.Textbox widgets. After selecting the species composition, the density of the plantation and the percentage of mixture, the user can either select an area for the analysis or run the prediction (apply button). Clicking the apply button calls **executionCarbonPredictor()**, which shows a loading message and triggers the **predictCarbon()** function with a 100 milliseconds timeout. The function **predictCarbon** is the responsible for the estimation of the future carbon and it integrates several key functions. First, it performs a quality control and checks that all the three species are selected, that the addition of the species mixture doesn't add up more than 100% and that the density value must be numeric. After checking the user inputs, the function calculates the biomass for each species, then retrieves a carbon estimation and generates a chart plotting the carbon evolution. This process has difference nuances depending on if there is a user selected area:

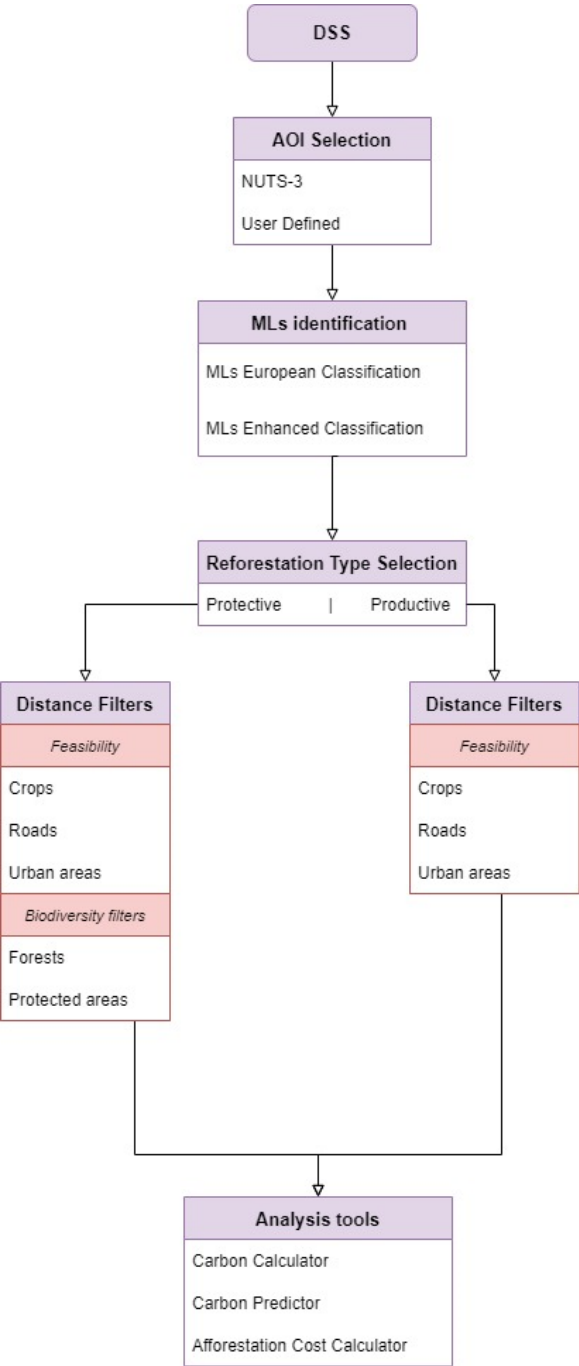




- If there is not a user defined area, **predictCarbon()** calls **calculate\_biomass\_sp\_noarea()** for each species. This function assumes a mean annual DBH increment value for each species, since an estimation of DBH increment cannot be run without a user defined area. Here, the future diameters were estimated for each species considering a time span of 50 years and an initial diameter of plantation of 1 cm. As a result, a list of predicted DBH values passed to the carbonCalculator **biomass\_eq** object which stores the generalized biomass equations for all the species in Europe. Finally, a list of biomasses predicted values is obtained and passed to the function **calculate\_total\_carbon** which will produce a carbon accumulated estimation that is plotted (**update\_carbon\_chart\_no\_area()**) to a ui.Chart showing the evolution of carbon in the plantation
- If there is a user defined area **predictCarbon()** applies a DBH increment model for each species. First, it retrieves the beta coefficients for the species using **select\_beta\_coefficient()** and then computes the biomass values for each species calling the **calculate\_biomass\_sp()**. As in **calculate\_biomass\_sp\_no\_area()**, the future diameters were estimated for each species considering a time span of 50 years and an initial diameter of plantation of 1 cm. As a result, a list of predicted DBH values passed to the carbonCalculator **biomass\_eq** object which stores the generalized biomass equations for all the species in Europe. Finally, a list of biomass predicted values is obtained and passed to the function **calculate\_total\_carbon** which will produce a carbon accumulated estimation. Before plotting the result, the total carbon is estimated for each marginal land class using **ee.reducerRegion()** over an **ee.Image.pixelArea()** masked for each ml class and multiplied for the carbon. Finally, the carbon evolution for each MLs class is plotted in a ui.Chart using **update\_carbon\_chart\_()**.

### 2.5.5 DSS development

The Decision Support System is presented as a framework inside the tool in order to filter and select the most suitable marginal lands for a reforestation project. The selection is based on user inputs that defines the area of interest and the distances from or to landcover areas to carry out the reforestation. Figure 18 summarizes the configuration of the DSS tool.



**Figure 18: Back-end workflow of the decision support system**

First, the DSS workflow starts by defining an Area of interest. The user is given two options to select the area: the first one is selecting a NUTS3 area defined by a GAUL level 2 `ee.FeatureCollection()` or defining a polygon using `Map.drawingTools()`. The area selection panel is composed by two sliders. The main slider (SLIDER NAME) allows the user to select the country of interest, then the country name is passed to the second



slider (SLIDER NAME) which filters the collection and retrieve a list of the NUT-3 for the country selected. If a NUT 3 is selected then the `ee.Feature()` is passed to the Function **collectGeometry()** that converts the country `ee.Feature()` selected into a `drawingTools()` layer so that the user can select several areas, both NUT3 or user defined.

Next step in the DSS is the identification of the marginal lands in the user defined area. at this step the user can choose between two options: the Marginal lands identified by the methodology proposed in task 2.3 and that is represented by the global variable “**mls**” and the MLs Enhanced Classification. To run the MLs Enhanced Classification, it requires a start and end date for running the classification. For this purpose, one `ui.DateSlider` is displayed to get select the start date, if the date selected is at least 2 years older than the present date, then another `ui.dateSlider` is displayed to select the end date. Next, both dates are passed to the function **enhancedClassification()** this function executes the workflow presented in the section “Augmenting Marginal land precision” as a result, it retrieves a marginal land layer based on a Random Forest classification.

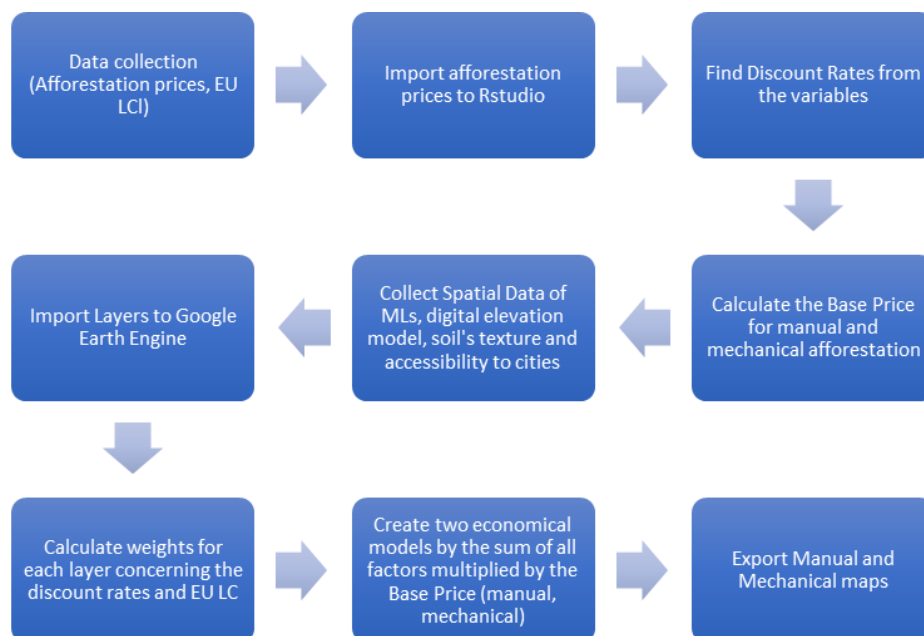
Continuing with the workflow in the DSS, after identifying the marginal lands distance filters are applied (to key landcovers) to select target MLs suitable for reforestation. The user must select the reforestation type to carry out using a `ui.Select` widget. Then, `ui.Panel` is displayed holding `ui.textBox()` widgets where the user must indicate the distance value close to a landcover type where the reforestation is to be performed. Additionally, it is given a checkbox to indicate that the distance introduced is regarded as distance further than the landcover of choice. Depending on the reforestation objective two sort of filters are applied: for protective reforestations feasibility and biodiversity filters are applied, whereas in the productive reforestation only feasibility filters are applied. The feasibility filters consider the distance to roads, crops and urban areas, on the other hand the biodiversity filters contemplate the distance to forest and protected areas. The apply button calls the function **generateDistances()** that generates a distance mask based on all the user specifications. In this function the distance values and the checkbox options are retrieved by the functions **getTextboxValues()** and **getCheckboxValues()** respectively. This information is passed to **applyThreshold()** that generates the single distance mask for each landcover type and collects them in a list. Then an `ee.ImageCollection.fromImages()` is computed using the list with the distance masks. After, a single distance image is generated using the `.and()`, where all

the non-zero value pixels are reclassified to one. Finally, this distance mask is applied to the **mls** or **enhancedMls** variable to obtain the desired marginal lands.

Once the reforestation areas are identified then these areas are passed to the carbon tools to assess both a present carbon content (carbon content) or a future carbon content (carbon predictor)

### 2.5.6 Reforestation cost calculator

In this chapter an economical model is created calculating the cost of plantation of one single tree. This model takes into account specific factors that influence the cost of the plantation such as the soil texture, the slope of the area, the manual or the mechanical way of the plantation, the accessibility to cities and the labour cost level of the countries in EU. After the ML detection from the Task 2.3 the areas with high suitability for forestry are used for the calculation of the price.



**Figure 19: Back-end workflow of the reforestation cost calculator.** Source: (Georgiadis et al., 2021)

Using as reference site the Spanish website 'Tarifas Tragsa', the prices for forest plantation were calculated. Three basic operations as the opening a hole on the ground (manually or mechanically), the plantation of one tree and the covering of the ground hole were taken into account in order to define the base price of planting a single tree. Since there were many factors that influence the price such as the slope of the ground,



the density of the trees, the consistence of the soil (loose, transit, rocky) and the size of the hole, an RStudio-script created for the base price definition and the percentage which each factor influences the base price.

After running the script above, the outcoming result was the base price by a manual way of planting a tree was 16.51 euros and the mechanical way was 5.28 euros.

While the aim of this procedure is to illustrate the factors that influence the price of tree plantation in marginal lands in spatial data, the factors that kept from the above process were the slope and the soil consistence. When slope is less or equal to 50% influences the price at -9% and when it is above 50% at 9%. When the soil is loose, the price is influenced at -60%, when it is transit at 16% and when it is rocky at 45%.

First of all, the most important map of Marginal Lands which produced in task 2.3 of [MAIL Project](#), imported in the platform of Google Earth Engine. Spatial data such as Digital Elevation Model (GTOPO30: Global 30 Arc-Second Elevation), Accessibility to Cities 2015 (Travel time to the nearest densely populated area), Texture of the soil by USDA Systems, were collected from Google Earth Engine's data Catalog. Moreover, due to the fact that the price of labour differs from country to country, Labour Cost level (LCI) which concerns compensation of employees plus taxes minus subsidies collected from Eurostat. The countries prices were estimated as weights using as base country Spain since the data for the computation of the base price came from there. In order to spatialize the LCI prices Nuts 0 shapefile was also collected by Eurostat and combined (by join in ArcMap) with LCI values.

ML's map has four classes, class 0, 1, 2 and 3, where 0 marginal land does not exist, 1 defined as Marginal lands with high plantation suitability, 2 as Marginal lands with low plantation suitability and 3 as potentially unsuitable lands. Since the aim of the model is the afforestation, ML map reclassified as binary map considering 0, 2 and 3 classes as 0 and class 1 as 1. This binary ML map multiplied by the base prices (manual and mechanical).

Furthermore, for the calculation of the distance of any ML to the nearest populated city, weights had to been calculated using the following equation:

$$W_{acc} = 1 - \frac{b_i}{b_{max}}$$

**Figure 20: Definition of the weight for the accessibility to cities**

Where,  $W_{acc}$  is the weight of the accessibility to cities,  $b_i$  is each value of accessibility to cities map (defined in hours) and  $b_{max}$  is the maximum value of accessibility to cities map. This new layer came out from the above equation multiplied with the ML binary map.

The Nuts level 0 shapefile with the weights of the LCI rasterized in GEE and the multiplied as well with the ML binary map.

From the Digital Elevation Model, slope was estimated by the function of Terrain.slope in GEE and converted from degrees to percentage. The slope reclassified into two categories of less than equal to 50% and greater than 50% and revalued as -0.09 and 0.09, respectively.

The Texture of the soil USDA layer is separated by twelve classes: clay, silty clay, sandy clay, silty clay loam, clay loam, sandy clay loam, silt, silt loam, loam, sandy loam, loamy sand, and sand. These classes reclassified to three, so clay, silty clay, sandy clay and silty clay loam assumed as loose soil and got the value of -0.6, the classes clay loam, sandy clay loam, silt and silt loam assumed as transit soil and got the value of 0.16 and the last loam, sandy loam, loamy sand and sand classes assumed as rocky soil and got the value of 0.45.

The European economic model for the forestation planting calculated by the following equations for manual and mechanical way of plantation:

$$manual = bp_{man} * W_{acc} + bp_{man} * W_{LCI} + bp_{man} * W_{sl} + bp_{man} * W_{soil}$$

$$mechanical = bp_{mec} * W_{acc} + bp_{mec} * W_{LCI} + bp_{mec} * W_{sl} + bp_{mec} * W_{soil}$$

**Figure 21: Equations for defining the prices of planting a tree in a given pixel both in mechanical or manual way**

Where,  $bp_{man}$  and  $bp_{mec}$  are the manual and the mechanical base prices, respectively,  $W_{acc}$  is the weight of the accessibility to cities,  $W_{LCI}$  is the weight of LCI based on Spain,  $W_{sl}$  is the weight of slope and  $W_{soil}$  is the weight of soil texture.



The afore mentioned methodology was imbedded in the function **costCalc()**. This function is called when the `ui.Button()` (apply) is activated on click. Two arguments are required to run `costCalc`, the **base\_price\_manual** (base price for manual operations i.e. dig a hole, plant, close the hole) and the **base\_price\_mechan** (base price for mechanical operations). Both base prices can be inputted by the user through `ui.textBox` widgets. If there is not, the default values will correspond to the values obtained using the R script.

## 2.6 Embedment of developed tools into the web application. Connection to GIS platform

The GEE Explorer is a simple web interface to the Earth Engine API. It allows anyone to visualize the data in the public data catalog. The explorer provides a seamless API to Google's standard front end user interface library which enables easy and fast development of Earth Engine Apps on top the analytical back end.

Earth Engine Apps are dynamic, shareable user interfaces for Earth Engine analyses. With Apps, experts can use simple UI elements to leverage Earth Engine's data catalog and analytical power, for experts and non-experts alike to use.

Apps published from Earth Engine are accessible from the application-specific URL generated at time of publishing. No Earth Engine account is required to view or interact with a published App. Apps selected as featured by their creator are also available at a user-specific App Gallery (e.g., `USERNAME.users.earthengine.app`). This document described the architecture and structure of the analytical procedures implemented in the **MAIL** project – back end.



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## **ANNEX III: SYLLABUS**

### **Duration**

5 weeks

### **Dedication**

4 hours a week

### **About this course**

The course is targeted to students, researchers, or stakeholders who are interested in the analysis and management of Marginal Lands (MLs). This course is designed in 5 units in which it is expected to transfer the results of the European project “*Identifying Marginal Lands in Europe and strengthening their contribution potentialities in a CO2 sequestration strategy (MAIL)*”. Project under the European Union's Horizon 2020 Marie Skłodowska-Curie research and innovation program (Grant Agreement No. 823805).

All videos are based on the procedures followed in the MAIL project for Europe, which means that some of the procedures described may not be exactly transferable to other parts of the world.

The mechanics of the course are simple: follow the learning sequences proposed by the platform by watching the videos and asking the questions and activities that are proposed. In some cases, you will find optional readings that you can read to expand on the subject.

### **What will I learn**

In this MOOC you will learn: (1) the definition of MLs; (2) a methodological proposal for the identification and classification of MLs; (3) a short review of forest biomass estimation with optical sensors, RADAR, LiDAR; (4) a proposal of carbon calculation; and (5) an introduction to the MLs management application created in GEE in the framework of the project.

During the course, we will give you some recommendations for the manipulation of large datasets and we will teach you how to work with the GEE application as a user. All this with the aim that you will be able to better understand the concept of MLs and will be able to analyze large MLs extensions in a fast way.





Within the course, you will have questions for self-evaluation after each video, weekly practice, and at the end of the course an exam where you will be asked about the content of the whole course.

### **Prerequisites**

You need a basic knowledge of the Internet as a user and access to the Internet.

For the practice, you need a word processor, QGIS, GEE, Rstudio.

### **Units**

1. Module 1: Definition & descriptions of MLs.
2. Module 2: Identification & classification of MLs.
3. Module 3: Biomass estimation from remote sensing data.
4. Module 4: Carbon storage and accounting.
5. Module 5: GEE based platform for MLs management.
7. Final exam.

### **Time scheduling**

The course is designed to do one unit and one practice per week. The final exam can be taken at the end of the complete content.

We have posted all the material from the beginning so you can do it at your own pace. All exams are closed at the end of the course.

### **Evaluation**

Only the final exam counts for passing the course, the practice and the questions placed after each video serve to reinforce what you have learned but do not count towards your final grade. You have 1 attempt to answer each

multiple-choice question. The course will be considered passed if the final score is equal to or higher than 50% of the maximum possible grade.

doubts, you can send an email to the corresponding teacher in each section.

The practices are self-evaluated, although if you think we can give you some comments or if you have many



## ANNEX IV: QUIZZES

Table 7 summarizes the subsections with practical exercises. All sections have a final exam.

Section	Subsection	Quiz	Section	Subsection	Quiz
1	1.1	-	3	3.1	✓
	1.2.1	✓		3.2	✓
	1.2.2	✓		3.3	✓
	1.3	-		3.4 (Unit Exam)	✓
	1.4	✓	4	4.1	-
	1.5	-		4.2	-
	1.6 (Unit Exam)	✓		4.3	-
2	2.0	-		4.4	-
	2.1	✓		4.5 (Unit Exam)	✓
	2.2	✓	5	5.1	-
	2.3.1	✓		5.2	-
	2.3.2	✓		5.3	-
	2.3.3	-		5.4	-
	2.4	✓		5.5	-
	2.5 (Unit Exam)	✓		5.6 (Unit Exam)	✓

Table 7: Quiz summary. Source: Personal compilation.

### A.1 Section 1

#### *Subsection 1.2.1: The concept “Marginal Lands” and its synonyms*

##### 1. Marginal land is:

- An unproductive land
- A productive land
- Somewhere between the above (\*)

##### 2. Which of them is marginal:

- A recreation park
- A degraded land (\*)



- An agricultural land

**3. One of the main ways CO<sub>2</sub> is removed from the atmosphere is:**

- Photosynthesis (\*)
- Combustion
- Respiration

***Subsection 1.2.2: Definition of “Marginal Lands”***

**1. Which driving forces for marginality are used by most authors?**

Environmental constraints and land cover / land use.

**2. Name two examples of marginal lands according to the definition.**

(Semi-) mountainous lands with naturally low productivity, abandoned agricultural and industrial sites.

***Subsection 1.4: The classification of MLs over time***

**1. The concept of marginal land is dynamic and evolves over...**

- Time
- Location
- Discipline
- Management objectives
- all answers are correct (\*)

**2. Indicate which project is not related to marginal land**

- SEEMLA
- MAGIC
- ITER (\*)

***Unit exam of Section 1***

**1. Is a crop field a marginal land?**

- Yes
- No (\*)

**2. Which of the below is true:**

- Marginality is strongly affected by latitude (\*)
- Marginality is static over time
- Marginality is not affected by production cost

**3. “Depth available to roots” dataset is necessary for assessing marginality**

- Yes (\*)



- No
- 4. Which of the below is more important for afforestation' species selection**
  - Average mean air temperature per decade
  - Average minimum air temperature of the coldest month per decade (\*)
- 5. Which term related to "Marginal Lands" is not widely used in science?**
  - Abandoned Lands
  - Degraded Lands
  - Underutilized Lands (\*)
- 6. Indicate which project is related to marginal lands:**
  - SEEMLA (\*)
  - GeoTAK
  - ITER
- 7. Under MAIL's framework, which is the main objective of the Land Use, Land Use Change and Forestry European regulation?**
  - Accounting the emissions and removals of carbon (\*)
  - Promoting reforestation
  - Environmental protection
  - Land use planning
- 8. What is the meaning of the concept multi-functionality of land?**
  - Multi-functionality of land means that every land has the capacity to provide different goods and services (\*)
  - Multi-functionality of land means that every land has the capacity to support different activities.
  - Multi-functionality of land means that on every land environmental protection function should be considered as priority.
  - None of the above.

## **A.2 Section 2**

### ***Subsection 2.1: Overall approach for the identification and classification of MLs – QGIS Example***

- 1. Which of the following land condition does NOT constitute a "hard" threshold, in the MAIL project methodology for detecting marginal lands?**
  - Area is covered by forest



- Area is covered by impervious surfaces
  - Area is protected
  - Area has large slope (\*)
  - Area is covered by permanent water
2. Which of the following land condition does NOT constitute a "soft" constraint, in the MAIL project methodology for detecting marginal lands?
- Area has large slope
  - Area has low fertility
  - Area has very high elevation
  - Area is covered by agricultural land (\*)
  - Area has high erodibility
3. You can import raster layers to your PostgreSQL geodatabase by using the PostGIS GUI:
- True
  - False (\*)

#### ***Subsection 2.2: Hard Layers for identifying MLs – QGIS example***

1. What is a “Hard Layer” according to MAIL methodology?
- Areas that are considered Marginal Lands
  - Areas that cannot considered Marginal Lands (\*)
  - Land Cover Areas after the elimination of Peatbogs and Marshes
2. Which of the following data sources can be utilized for the delineation of Urban areas?
- High-Resolution Imperviousness Layer (\*)
  - Global Forest Change products
  - CDDA polygons
3. What type of data are used for the delineation of potential Marginal Lands?
- Vector and Raster data (\*)
  - Only vector data
  - Only Raster data

#### ***Subsection 2.3.1: Soft constrains: Definition and processing***

1. In the MAIL project, what analysis was carried out with the soft indicators?
- They evaluated the degree of marginality of an area. (\*)

- They identified potentially marginal areas.
- Identified the areas in Europe most susceptible to climate change.

*Feedback: In the MAIL project, the soft indicators allowed us to analyze the marginality degree of the marginal lands identified with the HARD layers.*

## **2. The workflow followed in the analysis of soft indicators was:**

- Literature review, calculation of weights, PCM, normalized PCM.
- Literature review, identify the indicator threshold, normalized PCM, PCM, calculation of weights.
- Literature review, identify the indicator threshold, PCM, normalized PCM, calculation of weights. (\*)

*Feedback: The workflow followed in the MAIL project consists of analyzing the literature, identifying the thresholds for each indicator, performing the pairwise comparison matrix, normalizing the matrix and finally calculating the weight of each indicator based on the normalized PCM.*

### ***Subsection 2.3.2: Soft constrains: Definition and processing***

#### **1. The result of the soft indicator processing phase was a raster per indicator:**

- where each pixel contains the weight of the indicator.
- with 3 values that represent 3 categories of marginality. (\*)
- with the original values because it is better to perform the overlay.

*Feedback: The result of the processing phase of the soft indicator layers was a raster per indicator with 3 values representing the three categories of marginality. In some indicators, there were only two values that correspond to the high and low afforestation potential categories.*

#### **2. In the Mail project, were the subsoil and topsoil layers of the indicators used when this information was available?**

- No, because there was no indicator with this type of information.
- Yes, especially for "Total available water" and "slope".
- Yes, for indicators such as "Coarse fragments", "Texture", "Clay", "Sand", "Total available water", or "Soil organic matter". (\*)

*Feedback: In the European ESDAC repository you can find the "Coarse fragments", "Texture", "Clay", "Sand", "Total available water", or "Soil organic matter" layers with values at subsoil and topsoil levels. In the MAIL project, these databases were used.*

#### **Subsection 2.4: The ML classification scheme in the MAIL project**

##### **1. Identify the wrong answer:**

- in the MAIL project with the HARD layer, the marginal lands were identified.
- in the MAIL project with the SOFT layer, the marginal lands were classified.
- in the MAIL project with the SOFT layer the marginal lands were identified and classified. (\*)

*Feedback: In the MAIL project, HARD layers were used to identify marginal lands and soft layers were used to determine the degree of marginality.*

##### **2. The three marginal land categories defined in the MAIL project are:**

- Marginal lands with high plantation suitability, Marginal lands with low plantation suitability, and potentially unsuitable lands. (\*)
- Marginal lands with high slope, marginal lands with low slope and unusable marginal lands.
- Marginal lands with high suitability for mixed forest afforestation, marginal lands with low suitability for exotic species afforestation and potentially unsuitable lands.

*Feedback: In the MAIL project, the three marginal land categories defined are Marginal lands with high plantation suitability, Marginal lands with low plantation suitability, and potentially unsuitable lands.*

#### **Unit exam of Section 2**

##### **1. The number of times a soft indicator appeared in the literature was used to perform the ranking of importance of the indicators. This ranking is key to:**

- To identify marginal lands.
- To establish the weights of each indicator. (\*)
- To establish the thresholds of the indicators.

*Feedback: The number of times an indicator appeared in the bibliography was used to establish a ranking of indicators and based on this ranking, the normalized pairwise comparison matrix was used to establish the corresponding weights.*

**2. The workflow phases for processing soft indicators were:**

- Data download, reclassification based on defined thresholds and multiplication by indicator weight. (\*)
- Data download, multiplication by indicator weight and reclassification based on defined thresholds.
- None of the above.

*Feedback: The process followed in the MAIL project was to download the data from free repositories, reclassify the raster according to the thresholds established in the literature review and finally multiply the classified raster by the weight calculated in the Pairwise Comparison Matrix.*

**3. Once all soft indicator layers are overlapped, pixels can have values between 0.12-6.86 depending on their marginality. In this sense:**

- higher values represented high marginality
- higher values represent low marginality (\*)
- values close to zero indicate low marginality

*Feedback: Once the overlapping process is finished the pixel value can vary between 0.12 - 6.86 where the lowest value means that the indicators have a very low score and consequently are the most marginal areas. The higher the score, the lower the marginality.*

**4. Which of the following are considered as “soft” constraints in the MAIL methodology?**

- slope
- soil quality
- all of the above (\*)

**5. Which of the following data sources can be utilized for the delineation of forested areas?**

- Global Forest Change (Hansen et al., 2013) (\*)
- Copernicus High Resolution Imperviousness Layer
- JRC Global Surface Water

**6. How was the importance of each soft constraint defined?**

- all soft constraints were of the same importance in the analysis
- in a random way





- a rank was assigned according to the times a constrain appeared in the literature review (\*)
- 7. The “soft” constrain thresholds were applied uniformly for all areas across Europe.**
- True
  - False (\*)
- 8. One of the methods for defining the final classes of marginality is...**
- by splitting the classes using the min-max values of the final marginality layer, into 3 equal classes (\*)
  - by splitting the values of the final marginality layer into 5 equal classes
  - by splitting the final marginality layer, using only the values from 0-1
- 9. Which of the following “soft” layers needs further processing to be calculated?**
- Texture and Aridity (\*)
  - Slope, Water availability (topsoil and subsoil)
  - Clay (topsoil and subsoil), Sand (topsoil and subsoil)
- 10. To identify the final ML hard layer of the proposed methodology, all intermediate layers are...**
- all summed up using the “merge” tool
  - reprojected and reclassified into binary rasters (\*)
  - reprojected and normalized to values from 0-1

### A.3 Section 3

#### *Subsection 3.1: Remote sensing basics*

**1. Remote sensing uses which of the following waves in its procedure?**

- Electric field
- Sonar waves
- Gamma-rays
- Electromagnetic waves (\*)

*Feedback: Electromagnetic waves are used in the case of remote sensing. The different waves present in this spectrum enables us to use a variety of waves based on the condition present and can be able to have a better output.*

**2. Which of the following is not a principle of remote sensing?**

- Interaction of energy with satellite (\*)



- Electromagnetic energy
- Electromagnetic spectrum
- Interaction of energy with the atmosphere

*Feedback: Remote sensing involves certain principles which are applied for having a good result of the desired output. The principles are electromagnetic energy, electromagnetic spectrum, interaction of energy with atmosphere etc.*

**3. Which of the following is not a classification of scattering principle?**

- Wave scattering (\*)
- Rayleigh scattering
- Mie scattering
- Non-selective scattering

*Feedback: Scattering involves in distribution of the light ray in more than two directions. It can be further classified as Rayleigh scattering, Mie scattering, non-selective scattering.*

**4. Which one of the following helps to identify objects on the earth surface?**

- Signature (\*)
- Radiometric error
- Atmospheric window
- None of the above

*Feedback: Signature is the parameter that directly or indirectly characterizes the nature, and or condition of the object under observation, is defined as its signature. The Spectral signature of the object is used in remote sensing.*

**5. Which type of remote sensing uses its source of electromagnetic energy?**

- Active remote sensing
- Passive remote sensing
- Both Active & Passive Remote Sensing
- None of above

**Subsection 3.2: Optical sensors: Sentinel 2**

**1. Sentinel 2 has 13 spectral bands**

- True (\*)
- False

**2. Sentinel 2 mean altitude orbit is approximately 8000km**

- True



- False (\*)

*Feedback: Sentinel 2 mean altitude orbit is approximately 800km.*

**3. The multispectral band of Sentinel 2 can help us to:**

- map degraded forest
- Distinguishing healthy crops from diseased affected ones
- Distinguish healthy trees and dead ones due to its infrared bands
- All the above (\*)

**4. NDVI: It provides an excellent qualitative measure of the health and density of vegetation.**

- True (\*)
- False

**5. Optical remote sensing is an active technique for earth observation that relies on solar illumination for propagating radiations to the objects to be imaged.**

- True
- False (\*)

*Feedback: Optical remote sensing is a passive technique for earth observation that relies on solar illumination for propagating radiations to the objects to be imaged.*

**Subsection 3.3: “Radar sensors: Sentinel 1”**

**1. Sentinel 2 is a radar version of the Copernicus**

- True
- False (\*)

*Feedback: Sentinel 1 is the radar version of the Copernicus*

**2. SAR scans the earth's surface by other means either than microwave radiation**

- True
- False(\*)

*Feedback: SAR scans the earth's surface by other means of microwave radiation.*

**3. Sentinel 1 carries a S-band synthetic-aperture radar instrument which provides a collection of data in all-weather, day or night.**

- True
- False (\*)

*Feedback: Sentinel 1 carries a C-band and not S-band synthetic-aperture radar instrument which provides a collection of data in all-weather, day or night.*

**4. Sentinel 1 orbit has a daily repeat cycle and completes 175 orbits per cycle.**



- True
- False (\*)

*Feedback: Sentinel 1 orbit has a 12-day repeat cycle and completes 175 orbits per cycle.*

**5. Sentinel 1 is a product of the US space agency.**

- True
- False (\*)

*Feedback: Sentinel 1 is the first of the Copernicus Program satellite constellation conducted by the European Space Agency*

**Unit exam of Section 3**

**1. Remote sensing involves gathering of:**

- Sounds
- Images (\*)
- Changes
- Movements

**2. Which of the statements bellow is or are true (Multiple selection is allowed)**

- Multispectral and hyperspectral remote sensing refers to the measurement of the reflected spectrum ranging from UV wavelengths to shortwave infrared (i.e. 200nm - 25000nm)
- Thermal remote sensing refers to the measurement of the emitted thermal infrared radiation in the 11 - 15  $\mu\text{m}$  spectrum
- SAR or Synthetic Aperture RADAR refers to the measurement (in the form of imagery) of the backscatter of the microwave pulse emitted from the sensor.
- All of the above (\*)

**3. What is remote sensing (Multiple selection is allowed)?**

- Ability to gather information from a distant or unseen target using paranormal means or extra-sensory perception.
- Small or large-scale acquisition of information of an object or phenomenon not in physical or intimate contact.
- Any system that captures, stores, analyzes, manages, and presents data that are linked to location.
- All the above (\*)

**4. Atmospheric particles are able to completely absorbed incoming radiations**

- True



- False (\*)

*Feedback: It is a percentage of the incoming radiations that is absorbed during the atmospheric interaction*

**5. The electromagnetic spectrum is the range of frequencies (the spectrum) of electromagnetic radiation and their respective wavelengths and photon energies.**

- True (\*)
- False

## **A.4 Section 4**

### **Unit exam of Section 4**

**1. What instrument can we use to directly measure carbon fluxes?**

- flux towers or flux stations

**2. Which 5 main steps are required to perform a comprehensive carbon assessment?**

- Define area of study
- stratify the area
- Estimate the volume for each species or group of species
- Estimate for each stands of trees the allocation of biomass
- Transform the biomass into carbon

**3. What is a biomass equation?**

- It is a type of allometric equation that uses tree measurements and proportions to derive biomass

**4. Which three main remote sensing technologies help to improve biomass estimations?**

- SAR
- LiDAR
- Optical Data

**5. What Tier holds the highest level of accuracy in the IPCC Classification?**



– 3

**6. What is the difference between the Gain-Loss method and the Stock difference method?**

- The Gain-Loss method estimates carbon by subtracting the loss of carbon to the gain of carbon for a given time, whereas the Stock difference method performs the evaluation for the carbon stock at two different points in time.

**Exercises:**

- 1. Replicate the scripts in R, do you get the same results?**
- 2. Using the sources described in the exercise, replicate the carbon estimation for *Pinus sylvestris*.**

**A.5 Section 5**

**Unit exam of Section 5**

**1. What is the range of values presented in ML Land Productivity layer of MAIL Ma Portal**

- from 1 to 3.
- from 0 to 50.
- from 0% to 100%. (\*)

**2. Which online platform was used to create MAIL Map Portal?**

- Google Earth Engine. (\*)
- ArcGIS.
- Open Street Maps.

**3. What is the spatial extent of MAIL Map Portal?**

- Earth
- Europe (\*)
- Only Spain, Germany, Greece and Poland.

**4. Which online platform was used to create MAIL Map Portal?**

- Google Earth Engine. (\*)
- ArcGIS.
- Open Street Maps.

**5. What is Class 3 of the “Productivity classes” layer?**

- Areas with high suitability for trees



- Unsuitable areas for afforestation plans (\*)
  - Marginal Lands located on the lowest altitude.
- 6. For how many parameters user can modify the weight values in “Factors selection” tool of MAIL Map Portal?**
- 24. (\*)
  - 4.
  - 10.
- 7. What does DBH mean?**
- Decision Based Hypothesis.
  - Diameter at Breast Height. (\*)
  - Done, but how?
- 8. From the list of how many trees species user can choose in carbon predictor tool?**
- 5
  - 10
  - 17 (\*)
- 9. What parameters user can change in carbon predictor tools?:**
- Only the number of tree species
  - Number of trees per hectare, tree species, species composition mixture. (\*)
  - Only the number of trees per hectare
- 10. For how many years into future, carbon predictor estimates the amount of sequestrated carbon?**
- 50 (\*)
  - 25 (\*)
  - 1 (\*)