Climate Change Initiative Extension (CCI+) Phase 1

New Essential Climate Variables (NEW ECVS)

High Resolution Land Cover ECV (HR_LandCover_cci)

User Requirement Document

(URD)

Prepared by:

Università degli Studi di Trento
Fondazione Bruno Kessler
Université Catholique de Louvain
Università degli Studi di Pavia
Università degli Studi di Genova
Politecnico di Milano
Université de Versailles Saint Quentin
CREAF
e-GEOS s.p.a.
Planetek Italia
GeoVille

Changelog

Issue	Changes	Date
1.0	First version.	02/04/2019
1.1	Updated version according to CCI_HRLC_Ph1_Milestone1_RID-ESA.xlsx and comments in PM2.	12/04/2019
2.0	Updated version including final legend of high resolution land cover classes.	03/01/2020

Detailed Change Record

Issue	RID	Description of discrepancy	Sections	Change
1.1	URD-1	All the maps reporting the AOIs and the tables with the related coordinates should be the same in all the deliverables.	5.1, 6.5	All figures with the final areas are updated and uniform across deliverables. Note that Figure 1 and Figure 5 are not changed being the original ones presented in the proposal and at the VM, respectively.

Contents

1 Introduction

1.1 Executive summary

One of the activities included in Task 1 of the project is to update the User Requirements defined in the Technical document of the proposal of HR Land Cover CCI project [AD1]. With this aim, CREAF and LSCE conducted a user consultation among the climate and vegetation modellers community. This consultation consisted, first, in a survey sent to potential users and the collection of feedbacks from climate users, CMUG and other CCI projects participants (e.g. CCI Permafrost and CCI-Land Surface Temperature), followed by, second, a virtual meeting with potential users that was dedicated to collect their feedbacks on the questionnaire analysis. This document synthesizes the results of this survey and presents the updated requirements. The user requirements concerning the products that will be generated and their associated metadata are:

- Three studied zones centred on Amazonia, Sahel and Central Siberia (see Figure 7 and Figure 22) including each:
    - a large continental region on which LC will be mapped for year 2019, at 10 m resolution;
    - a sub-region inside, where LC will be mapped at 30 m resolution on the period (1990-2019) with a 5-year cycle and LC changes will be provided each year.
- The classification system should be based on LCCS approach upgraded to LCML/LCCS3.
- Full consistency with the MRLC product should be provided.
- The generation of side products characterizing vegetation seasonal activity, snow cover, water extent, burned areas at the same resolution (if feasible within the available resources) would be useful.
- The consistency in the LCC time series and between products should be carefully checked.
- Post-processing tools containing cross-walking tables linking LCSS classes to generic Plant Functional types (PFT), aggregation/projection tools to predefined grids, in addition to visualization and plotting facilities would be useful.
- The data should be delivered in GeoTIFF and NetCDF formats and the metadata in TXT and XML.
- Uncertainties should be characterized thematically and at pixel level.

1.2 Purpose and scope

This document describes the activities and results for the user requirement analysis (WP1100) for the product specification as part of the HR Land Cover CCI project within ESA's Climate Change Initiative Program. The overall objective for the HR Land Cover CCI project is to study and investigate the role of the spatial resolution of Land Cover and Land Cover Change in supporting climate modelling research. HR Land Cover CCI aims at improving the understanding of the interactions between climate and land surface while increasing the spatial resolution of one order of magnitude (from 300 m to 10 m) with respect to the previous MR Land Cover CCI project.

The WP1100 is the specific WP for the Phase 1 of the Task 1 of the project. The overall objective of Task 1 is to update the user requirements accounting for the needs of other climate modellers and for the end user needs. The main purpose is twofold:

- to benefit from new validation data (concerning land cover but also existing surface variables or fluxes to validate the climate simulations);
- to enlarge the climate model assessment, with possible integration in the project activities of other simulations using different climate models and advices from end users working on mitigation/adaptation questions.

In order to gather this information, we have implemented the methodology detailed in Section 3 of the present document and the following tasks assigned to WP1100 have been developed:

- Report the preliminary user requirements.
- Identify vegetation and climate modellers to be involved in the user requirement refinement.
- Organize the virtual user meeting with potential vegetation and climate users.
- Analyse user feedbacks on the use of preliminary HR land cover datasets.

- Collect data for additional assessment of user needs.
- Refine product specifications, the needs in terms of yearly historical product and seasonal related variables (referred as 'conditions').
- Links with the CMUG and other CCI+ projects.

1.3 Applicable documents

Ref.	**Title, Issue/Rev, Date, ID**
[AD1]	CCI HR Technical Proposal, v1.1, 16/03/2018

1.4 Reference documents

Ref.	**Title, Issue/Rev, Date, ID**
[RD1]	The Global Climate Observing System: Implementation Needs, 01/10/2016, GCOS-200

1.5 Acronyms and abbreviations

CCI	Climate Change Initiative
CRC	Climate Research Community
CMUG	Climate Modelling User Group
CREAF	Centre de Recerca Ecològica i Aplicacions Forestals
ECV	Essential Climate Variables
ESM	Earth System Models
EVI	Enhanced Vegetation Index
GCOS	Global Climate Observing System
GDPR	General Data Protection Regulation
HR	High Resolution
LAI	Leaf Area Index
LC	Land Cover
LCC	Land Cover Change
LCCS	Land Cover Coverage Classification System
LCML	Land Cover Meta Language
LCZ	Local Climate Zone
LSCE	Laboratoire des Sciences du Climat et de l'Environnement
MR	Medium Resolution
NDVI	Normalized Difference Vegetation Index
PFT	Plant Functional Type
RS	Remote Sensing
SFT	Surface Functional Type
SoW	Statement of Work
URD	User Requirements Document
VM	Virtual meeting
WP	Work Package

2 Preliminary user requirements

The Climate User Group involved in this project, defined three large test areas (see Figure 1) of particular interest to study the climate/LC feedbacks. These test areas cover 3 different continents, climate (tropical, semi-arid, boreal) and present complex surface atmosphere interactions that have significant impacts not only on the regional climate but also on large-scale climate structures. These interactions and the associated vegetation/atmosphere feedbacks are still poorly captured by state-of-the art Earth System Models (ESM), not to mention their future evolution which is highly uncertain. Additionally, these regions are critical for the global carbon cycle through the uptake of carbon by terrestrial ecosystems; they cover major biomes that are vulnerable from the point of view of land carbon stocks (tropical forest, permafrost…).

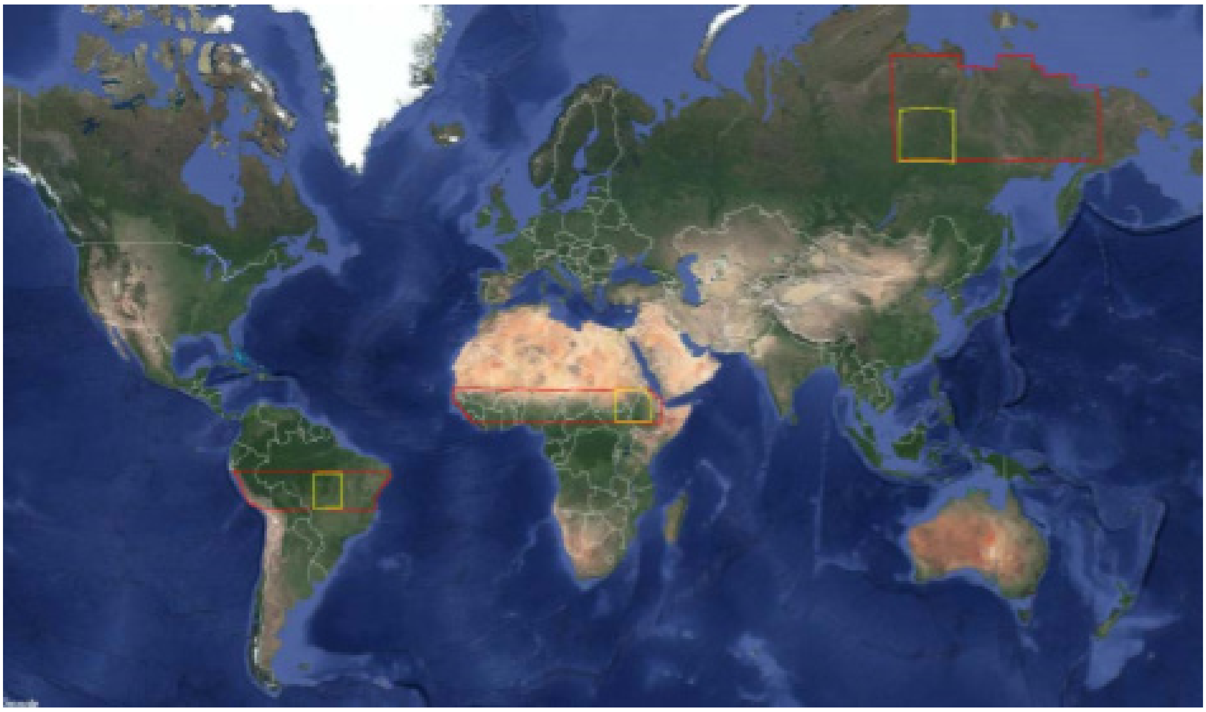


Figure 1: Location of the 3 regions defined in the project proposal to study climate/LC interactions. The red contours delimit the large regions where the static HRLC map will be produced, the yellow ones, the restricted areas where LC will be mapped over the last 30 years.

Amazon. The first region concerns the Amazon basin which has for several decades focused the attention of the scientific community due to large deforestation rates and potential associated large-scale climate impacts. Agricultural expansion and climate variability have become important agents of disturbance in the Amazon basin, mainly in the southern and eastern portions. Although Amazonian forests have considerable resilience to moderate annual drought, the interactions between deforestation, fire and drought potentially lead to losses of carbon storage and changes in regional precipitation patterns and river discharge with some signs of a transition to a disturbance-dominated regime.

Africa. The second region that draws our attention is the Sahel band in Africa including West and East Africa which is a complex climatic region which experiences severe climatic events (droughts in the 70's and 80's and floods more recently) often attributed to climate warming and for which the future predictions (amplitude of the regional warming and rainfall changes) are very uncertain. Present climate and especially the position and seasonal dynamics of the monsoons (the West African and the Indian ones) are generally not correctly represented in most of the climate models. Recently, many studies highlighted the key role of the surface processes on the representation of the near surface meteorological variables and their consequences on the turbulence in the mixing layer and the initiation of the precipitation. In the eastern part of the Sahelian band, the role of El Nino in the initiation of dramatic drought events in the horn of Africa is also not really understood and deserves more work to better predict and help mitigation studies.

Siberia. The third region is situated in the northern high latitudes, for which future climate changes are expected to be particularly strong, a phenomenon known as polar amplification. In Siberia, complex climate feedbacks over land, implicating natural and human factors, may further amplify these changes and make this region as a possible hot spot of future climate changes. Siberia represents 10% of land surface and 30% of forested surfaces globally. The warmer temperatures and increased winter rainfall have promoted increases in biospheric activity and longer active seasons. LC changes have been reported with the displacement of the forest-shrubs-grasslands-transition zone to the north. In addition, changes in LC may impact directly the fate of the carbon stored in permafrost, which in turn will affect long-term terrestrial carbon balance and ultimately climate change.

The technical section of the project proposal [AD1] includes a preliminary list of user requirements for each study region in order to investigate the role of LC on climate and vice-versa:

- A static map (for a recent year, i.e., 2019) of a large domain at sub-continental scale where the surface/climate interactions have already been highlighted by climatologists, i.e., the Sahel band in Africa influenced by the African (in its western part) and the Indian (eastern part) monsoons, the Eastern part of Siberia including a latitudinal transect at the taiga/tundra transition zone, the southern part of the Amazon basin including a longitudinal transect to study the Atlantic and Pacific ocean specific influences.
- Inside these large domains, sub-regions were defined to analyse the historical LCC over the last 30 years on a 5-year basis. These restricted regions with historical LCC maps will be more suitable to analyse potential on-going climate Mitigation/Adaptation actions.
- Related land surface seasonality products (when feasible in terms of data availability) as provided in the ECV MRLC project[1] like the average and inter-annual seasonal dynamics of the vegetation as captured by a vegetation index like EVI, burnt area extension, water bodies extent dynamics.
- Visualization and aggregation tools like the ones developed within the ECV MRLC project as the HRLC products are expected to be quite large and should be easily aggregate at the model cell scale while compiling the distribution of the PFT within this cell. These tools will facilitate the use of HRLC data by climate and vegetation models usually working at lower spatial resolutions.
- Specifications in terms of projection, file format and metadata content should at least correspond to the one provided within the ECV MRLC project.

These requirements answer those listed by GCOS [RD1] in terms of frequency and resolution (see Table 22) and they are suitable for climate modelling. They should be satisfactory also for most of the regional and mitigation activities linked to carbon ecosystem storage.

The primary aim of the Task 1 of the project is to update the user requirements accounting for the needs of other climate modellers and end users in terms of study sub-region, side products (including ancillary data and error characterisation) as well as distribution format. The idea is twofold: i) to benefit from new validation data (concerning land cover but also existing surface variables or fluxes to validate the climate simulations) and, ii) to enlarge the climate model assessment, with possibly other simulations using different climate models and advices from end users working on mitigation/adaptation questions. To gather this information, we have organized at the beginning of the project, a survey and a virtual user consultation workshop within the European climate modelling/users community extended to some of our strong US collaborators.

[1] https://www.esa-landcover-cci.org/

3 Methodology to retrieve User Requirements

3.1 Creation of the Climate Research Community

The first action in order to create the Climate Research Community was the collection of a list of potential members. The initial version of this list is the *List of potential key users* of the Technical proposal document that responds to the call [AD1]. This initial list was significantly growing up at the beginning of Task1 and with small and constant increase during the next Task 1 related activities. We sent a personal email with an invitation letter (Figure 2) to be part of the community. This letter explained the aim of the project and the role of the CRC. It also provided a link to a voluntary registration to https://mailchi.mp/76bf36dea1a2/esaccihrlc_signup. This procedure was designed in accordance with the EU GDPR[2] rules.

Each interested user was free to register to the community portal and once registered it received a welcome letter. Additionally, this registered user was included in a list of distribution info@esa-ccihrlc.eu with the option of be removed at any time with a simple action.

climate change initiative

high resolution
land cover

esa

Dear Dr. ,

Within the framework of European Space Agency (ESA) Climate Change Initiative, the "High Resolution (HR) Land Cover (LC) Essential Climate Variable (ECV)" project, which started in September 2018, involves the accurate description and analysis of land cover and LC change (LCC) using Earth Observation (EO) data with high spatial resolution (10-30m) (http://cci.esa.int/HRLandcover).

An essential feature of CCI is to implement a coherent and continuous suite of actions that encompasses all steps necessary for the systematic generation of relevant Essential Climate Variables (ECVs), and ensures their regular updating on timescales corresponding to the increasingly urgent needs of the international climate modellers and users community.

Figure 2: Invitation letter sent to all the personal contacts.

[2] https://ec.europa.eu/commission/priorities/justice-and-fundamental-rights/data-protection/2018-reform-eu-data-protection-rules_en

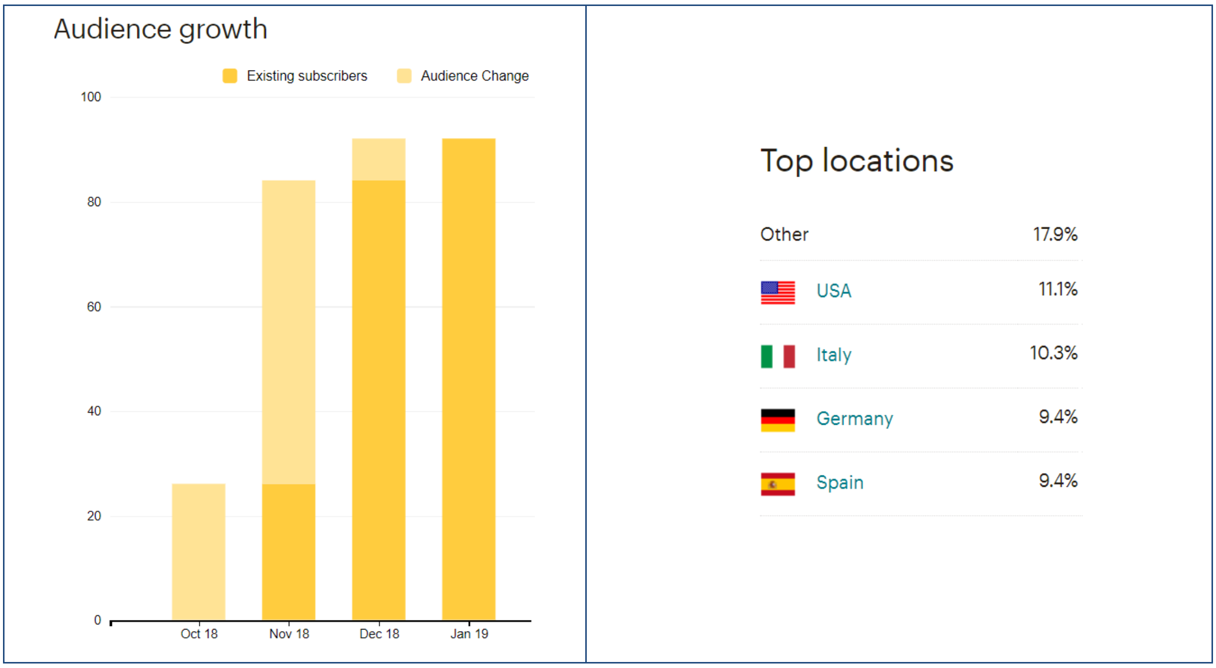


Figure 3: Left: Monitoring of subscribers. Right: Geographical distribution (top country locations) of the subscribers

All registered members received and will receive all community news (*i.e.* invitation to participate to the survey, virtual meeting announcement, etc.). Figure 3 shows the evolution and geographical composition of the community at 12/02/2018.

3.2 User survey: step 1 (User list and Questionnaire)

The aim of the ESA CCI High Resolution Land Cover presentation questionnaire was twofold. First, the questionnaire covered the function of presentation and dissemination of the project, informing about the activities and the study areas by attaching a link/document with such information. Second, the questionnaire was designed as the main tool to collect the user's views and requirements of the project in relation to:

- the location of the studied areas in relation with the climatological stakes;
- the temporal frequency needed for the land cover change maps;
- the land cover classification nomenclature;
- the way to assess and produce land cover uncertainties;
- the documentation needed;
- the needs for post-processing tools;
- the potential use within the climate community;
- the potential interests to participate in inter-comparison projects;
- the potential interests to participate in model evaluation.

Specifically, the survey consisted of 15 groups of questions of different nature (yes/no, multiple responses, open responses). The questionnaire was accepting responses from 17th December 2018 to 22nd February 2019 (note that most contributions were sent later than 7th January, after Christmas/Winter holidays). An invitation to participate to the questionnaire was sent to the 117 subscribers of the CRC at the time.

Additional feedback from climate users (e.g. Meteo France or MPI-Jena teams who did not received the questionnaire because of mailing issues) and of CMUG and other CCI projects participants (e.g. CCI Permafrost and CCI-Land Surface Temperature) was also collected and treated as complementary answers to the survey.

3.3 User survey: step 2 (Virtual Meeting)

The virtual meeting took place on 8th of February 2019, from 2 pm to 4 pm. The time was fixed in order to facilitate the participation of both European and American attendees (following the previous geographical distribution of the participants, see Figure 3). The launching platform used was gotomeeting[3].

The agenda of the Virtual meeting is included in Section 6.3.1. It was divided in:

- An introduction of the session to introduce the participants and the context of the project. It was presented by the organizers (LSCE) and co-organizers (CREAF).
- A participatory part with open discussions related to some selected questions of the survey distributed some weeks ago. The discussions were launched with very short presentations of the questionnaire results organized by topics (location, class legend, side products, post-processing tools, uncertainties).

3.4 Internal meetings

During the first cycle of the project some key requirements have been discussed in internal (virtual and in person) meetings between EO Science, Climate and Validation teams of the project. In addition, some specific presentations in Progress Meetings with the participation of all partners and ESA technical officers conducted to questions, answers and new updates of the previous requirements.

This interchange of approaches and opinions has been very fruitful and joined to the previous background, it concluded in the current version of requirements.

4 Final Outcomes

4.1 Outcomes of the questionnaire

The total number of completed answered surveys was 37. Figure 3 shows the geographic distribution of subscribers and Figure 4 the respondents to the survey.

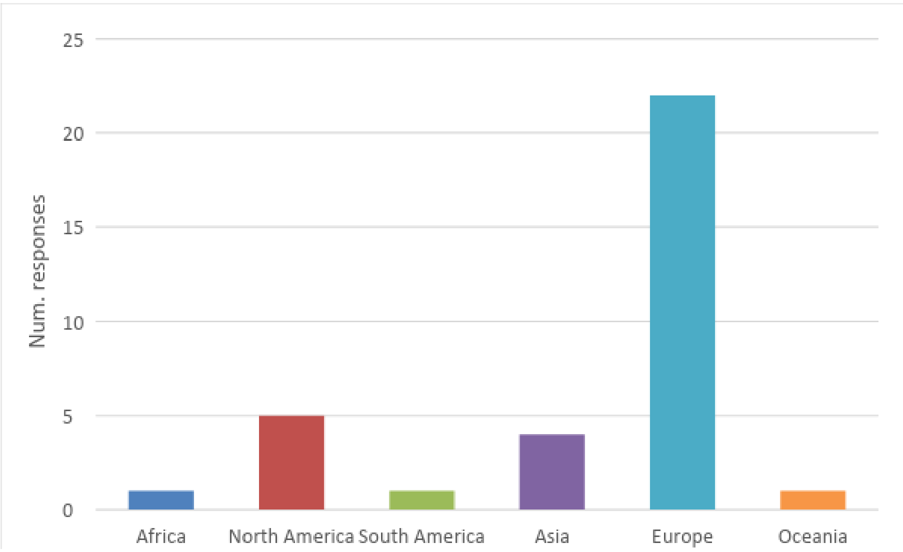


Figure 4: Global dispersion (per continents) of the users that completed the survey.

Concerning the provision of the results of the questionnaire, the complete results can be found in the Annex 6.3 . A specific summary of most relevant items, including some selected questions of the survey (in italics) and some particular and aggregated answers (in many cases, in the same line of the participants' recommendations expressed in the virtual meeting), is commented hereafter.

[3] https://www.gotomeeting.com

4.1.1 On the choice of the study regions

The main question of this section is:

- *What are your advices on the pre-selected regions (requirements for the precise location and spatial extent of the studied regions)?*

Most of the answers agreed on the preliminary regions, some of them with small movements and in general a higher dispersion of new locations in order to cover wider latitude ranges.
Some proposals are too far from the project goals: global coverage, Mediterranean, South Asia, Alaska, Greenland, Canada or Finland, etc.

4.1.2 On the spatial resolution

- *Please, indicate your needs in spatial resolution:*

The preferred spatial resolutions are 10 and 30 m.

- *How will you use a static map at 10 m resolution for 2017 and 30 m resolution for the 5-year land cover change products?*

Some selected answers are: parameterization and validation different models, impact analysis of particular land cover change as forest degradation, hydrology.

- *How will you take benefit of the increased spatial resolution compared to Medium Resolution products (300 m)?*

More accuracy, in general.

4.1.3 On the temporal resolution and extent

The summary of the responses related to temporal resolution and extension is:

Some (62%) agreed to 5-year period and some additional higher frequencies have been proposed: a 3-year period, bi-annual and annual. Annual is the most demanded.
Most of answers (84%) agreed on the extension of the proposed period (1992-2017). Some answers suggest to extend to the period of first Landsat images, from 1979 or 1984. There are few impossible demands like extending the period back to 1950.

4.1.4 On the product classification system and delivery formats (including documentation)

73% of participants agree with FAO LCCS categories. Most of the participants did not know about LCCS/LCML system and some of the answers reflect this lack of knowledge. The main proposed changes are:

- Vegetation related requests:
    i. Phenology classes and shrub classes.
    ii. CAVM – Circumpolar Arctic Vegetation Map or GlobPermafrost.
- Water or soil related requests:
    i. FAO-LCCS but with adaptation for hydrologic purposes.
    ii. Thermokarst lakes category.
    iii. Other landforms indicative of permafrost's.
- Urban related requests:
    i. More than one class for urban categories

GeoTIFF and NetCDF are the preferred formats for data and plain TXT for metadata. There is a wide range of responses in tile distribution form.

4.1.5 On the side products

- *Which side products would be the most relevant for your studies? If OTHERS, please indicate which ones*

Vegetation indices, seasonal variables and snow/ice flags are the preferences.

4.1.6 On the post-processing tools

76% of participants are satisfied with the tools developed in previous MRLC project. There are no relevant suggestions in this question.

4.1.7 On the uncertainties

- *Would these uncertainties be sufficient? If NO, what would you need?*

Some specific responses are: quantitative uncertainties and per pixel/raster information.

- *How will you use uncertainty information in your studies?*

Some specific answers are: weighting models, evaluate the data accuracy, etc., although a few responses are in line of "most likely I will not use the uncertainty information".

4.1.8 On the interest to be involved in the product assessment tasks

Around 54% of the participants are self-defined as Climate and global land surface modellers. The rest are other type of researchers.

4.1.9 Product assessment for modellers

Table 16 in Annex 6.3 lists the several models used by the participants: the two most used are ORCHIDEE and JSBACH.

Around 50% of participants are interested in participating in the assessment tasks, some of these participants would be able to collaborate in the assessment activities in the chosen regions for the project' case studies.

The modeller participants plan to use HR LCC for different purposes such as boundary conditions, evaluation, inputs, etc. and impacts of LCC in climate.

4.1.10 Product assessment for other users

The other (non-modeller) participants plan to use HR LCC for different goals and applications such as evaluation of ecosystem services, NPP and water cycles monitoring, damage assessment, etc., see Table 20 .

Most of them (65%), will use HRLC products in combination with many types of auxiliary data: other remote sensing products (optical, thermal, LIDAR, etc.), vegetation indices, LAI, see Table 21 .

4.1.11 On the interest to be involved in the product/modelling validation tasks

Most (75%) participants don't produce data in the preliminary study regions. We got 82% of positive cases who would share data depending on the conditions, a 9% that ever would share, and a 9% that never would share.

4.2 Outcomes of the Virtual Meeting

In this section, we report the aspects which were mostly discussed in the virtual meeting as well as the additional information obtained from direct feedback. The meeting had 28 attendees. The most participatory discussion was about the location of the case study regions and the legend classification.

4.2.1 Study zones

The location of the 3 study regions was the first aspect discussed. The discussion was based on a revision of the preliminary maps resulting from the user survey (see slide 26 of VM in Annex 6.4.2 and Figure 5).

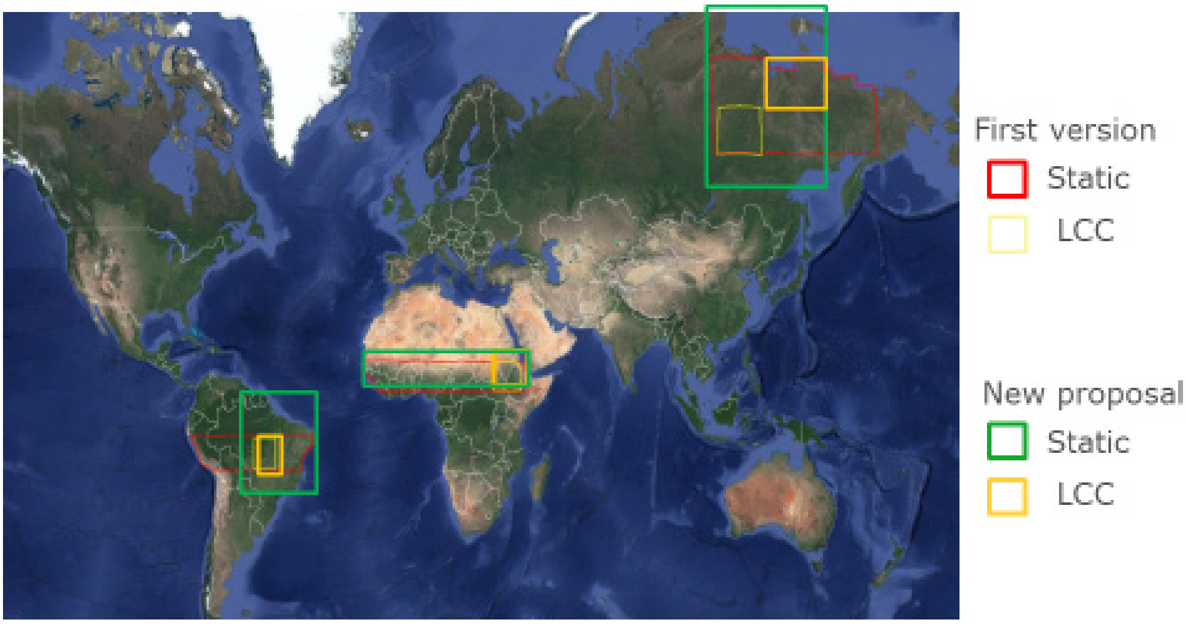


Figure 5: New proposal of study zones as presented at the Virtual Meeting discussion.

Compared to the original regions, some changes were proposed in order to map a larger diversity of ecosystems and to cover some areas of interest indicated by some potential users (i.e., Surinam, Tapajos and Gran Chaco regions in South America, northern Sahel and a larger North-South transect in Siberia). It should be noted that these changes were decided after the discussions at the first progress meeting in Trento with ESA and the consortium, when it was decided not to follow some suggestions to add other regions of interest or to move away from the 3 ones previously defined, although some users show their interest for Europe, South Asia, Central America, Canada or USA and found regrettable that temperate ecosystems were not mapped.

These choices were presented and argued at the VM. The discussions confirmed the added value of the new regions, confirming the interest to map a larger diversity of forests and crops species, the location of the LCC regions was also discussed and the proposition to move the Siberian zone to the north-eastern part of Siberia appeared not ideal because of larger relief and lower interest for climate change studies.

In summary, the main criticisms for the 3 zones were the following:

- For **Amazonia**: the static region should be extended to the North to cover more rainforest, and to the South in Gran Chaco to map a larger diversity of crop types. The existing FluxNet[4] station near Manaus (ATTO station), the Mato Grosso and Gran Chaco regions which experienced large deforestation and crop increase during the last 30 years are definitely worth mapping at yearly scale. The LCC region should therefore be extended to the South.

- For **African Sahel**: the static region should be extended to the South to cover the Equatorial zone, especially Guinea where large deforestation occurred. Western Ethiopia and South Soudan are regions which experienced also land degradation linked both to deforestation and climate change. The original region defined for LCC mapping could be kept, although western Africa presents strong interest also.

- For **Siberia**: the static region should be extended westward to cover the west Siberian plain studied by some German climate groups and the Yamalo-Nemets region studied by some Russian collaborators. The LCC region should be centered on the original proposition in Yakoutia where the impacts of climate warming on permafrost and vegetation are already significant and the vulnerability of the infrastructures and the population are the largest (as shown in [1]), compared to the dryer regions of the Eastern part of Siberia, where the soils present

[4] http://fluxnet.fluxdata.org/

less ice content. The existence of the FluxNet ZOTTO station north-west of the city of Krasnoyarsk, presents also strong interest for model validation.

4.2.2 Legend classification

The legend classification was the second point discussed. Participants agreed in adopting the LCML classification system, which should allow adding some attributes permitting to separate the crop species, assess the organization of the vegetation and surface roughness and better characterize urban areas.

Concerning the **crops**, participants insist on the importance of being able to separate permanent and annual crops (example of olive orchard and wheat which are both crops although presenting very different water and carbon functioning), irrigated and rainfed cultures, summer and winter crops (corn and wheat at least). Any information on management practices could be also very valuable (row crops or not, flooding or sparkling irrigation, crops rotation, number of cycles per year, etc.).

Concerning the **urban classes**, a single class 'Urban' is definitely not enough for climate modelling. It is needed to separate built-up areas, vegetation, artificial surfaces, roads, etc. (as allows the LCML system), because these objects present very different impacts on hydrological and carbon processes. It was also recalled that climate models need to prescribe surface roughness, therefore any information on building/trees heights is highly valuable. Met Office suggested to look at the Local Climate Zone (LCZ) framework (http://www.wudapt.org/lcz/lcz-framework) developed in [2] used to characterize urban areas based on temperature regimes.

Concerning the other **types of vegetation**, it is important to assess information on the spatial organization, for examples, trees in a forest, bushes in savannahs (tiger bush or not), and also on the land use, to distinguish natural and anthropogenic vegetation, grasslands and pastures (grazing or not), etc.

Concerning the **Siberian ecosystems**, the permafrost areas present very specific features that could be categorized: for example, thermokarst lakes, polygonal landscapes, ice edges, etc.

4.2.3 Side products

The strong interest for side products already noted in the questionnaire was reaffirmed. Besides all the seasonal variables which were already produced in the MRLC project, topographic information like topography and aspect were highlighted. The inter-consistency between the side products, intra and inter annually, should require much attention.

4.2.4 Format delivery

In addition to what appeared in the questionnaire results, the climate modellers would like to get the data and the metadata in the same NetCDF file.

4.2.5 CMC enrolment

The last point discussed was the interest to join the product assessment work. Despite the strong interest of the participants, no real proposition was made. It was said that without funding, even if the data are made available and easy to use, it will be difficult for them to commit. A. Hartley (Met Office) suggested that some work could be done in the framework of the follow-on MRLC project (to be discussed with ESA) and that Met Office produced high resolution (4km about) atmospheric forcing other whole Africa and Brazil on the last 10 years, that could be provided and used as common input for inter-comparison exercises.

5 Synthesis of User Requirements

In this section, we present a new version of the user requirements, updated with the user consultation and taking benefit of discussions/reviews within the CRC including the CMUG and other CCI groups through our attendance to the CMUG and co-location meetings. These requirements have been transmitted to the project consortium and are the basis of the PSD and DARD documents at K0+6.

The user requirements concerning the products generated and the metadata associated are presented in the following sub-sections.

5.1 Key areas location

As a result of the key users consultation, giving advantages to climate modellers demands (especially MPI and Met Office who participated both to the questionnaire and VM), the 3 studied zones were kept but were extended and moved to map a larger number of ecosystems and regions that are of interest for other ongoing studies (for example the region of the SODEEP project [5]of MPI team or Equatorial Guinea for Met Office).

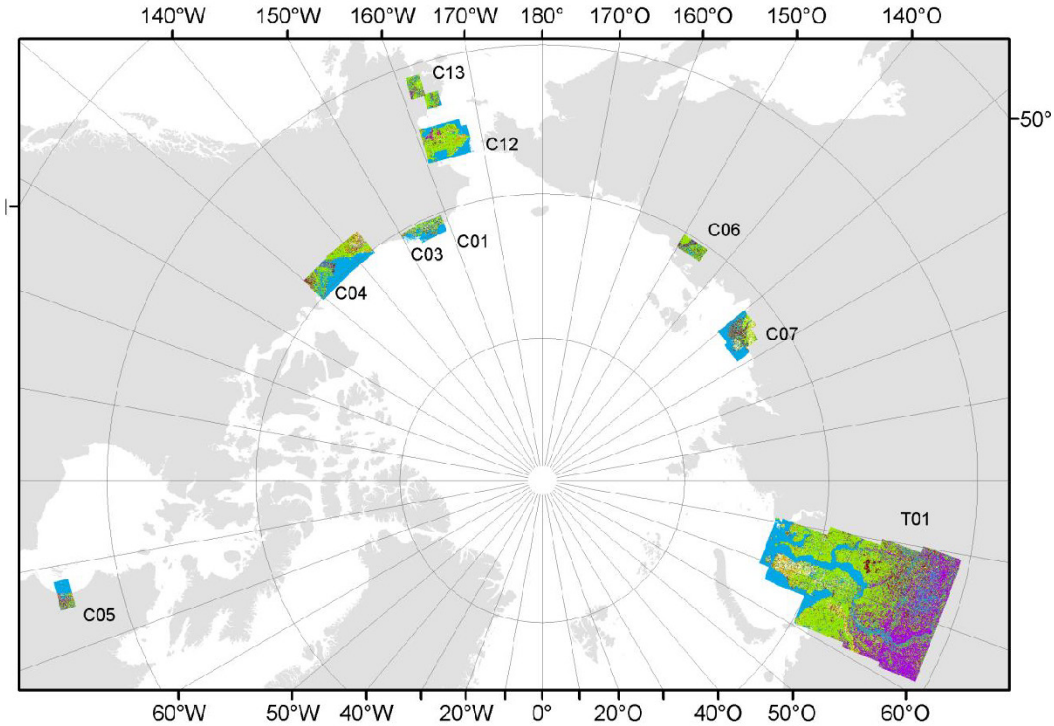


Figure 6. Regions mapped by the GlobPermafrost project.

Extensions in the latitudinal gradients were chosen rather than in longitudinal ones to cover a larger diversity of climatic zones in order to better assess climate-surface relationships. The locations were also optimized to include a maximum number of FluxNet stations (*in situ* site with eddy covariance flux measurements), which could be used to validate methods and models (example of ATTO and ZOTTO stations in Amazonia and Siberia respectively). We accounted also for the river basins contours in order to map as much as possible entire catchments. For example, we extended to the South our static region, to include the whole catchment of Lena river in Siberia. In the same way, in Africa, we extended the study zone to the North, to catch the whole Senegal river basin and to the East, to include the whole Awash river basin.

The LCC smaller regions were also slightly revised (especially for Amazonia) to include hot spots of deforestation (in Amazonia) or land degradation (in Ethiopia) or permafrost degradation in Yakutia (Siberia). Concerning this last point, we use the global permafrost map from the National Snow and Ice Data Center [3], to verify that our regions cover a large diversity of frozen soil types, ranging to continuous, discontinuous and sporadic permafrosts.

We have checked also that our regions are not already covered by other land mapping projects, in particular the ESA-DUE GlobPermafrost project which produces land cover maps in boreal/arctic regions. Concerning this last

[5] https://wiki.coast.hzg.de/display/HYD/SODEEP/

point, the regions mapped by the GlobPermafrost are shown in Figure 6.

The Yamal peninsula, the Lena delta and the Kytalik zones already mapped with Sentinel 1 and 2 data, could be defined as test zones in our project, taking advantage of the experience of the GlobPermafrost project, in order to better define and classify the vegetation types in the Arctic. The other way round, the CCI-Permafrost project would take advantage from high resolution land cover mapping on the overall circumpolar Arctic, the two projects will therefore profit from a strong collaboration. In summary, the geographical coordinates of the three regions are the following:

Amazonia:

Static map: (24°S -9°N; 34°W - 62°W)

Historical LC and LCC map: (24°S - 12°S; 47°W - 62°W)

Sahel:

Static map: (0°N - 18.5°N; 18°W - 43.5°E),

Historical LC and LCC map: (4°N - 16°N; 27°E - 43.5°E)

Siberia:

Static map: (52°N - 79°N; 65°E - 142°E),

Historical LC and LCC map: (60°N - 74°N; 65°E - 86°E).

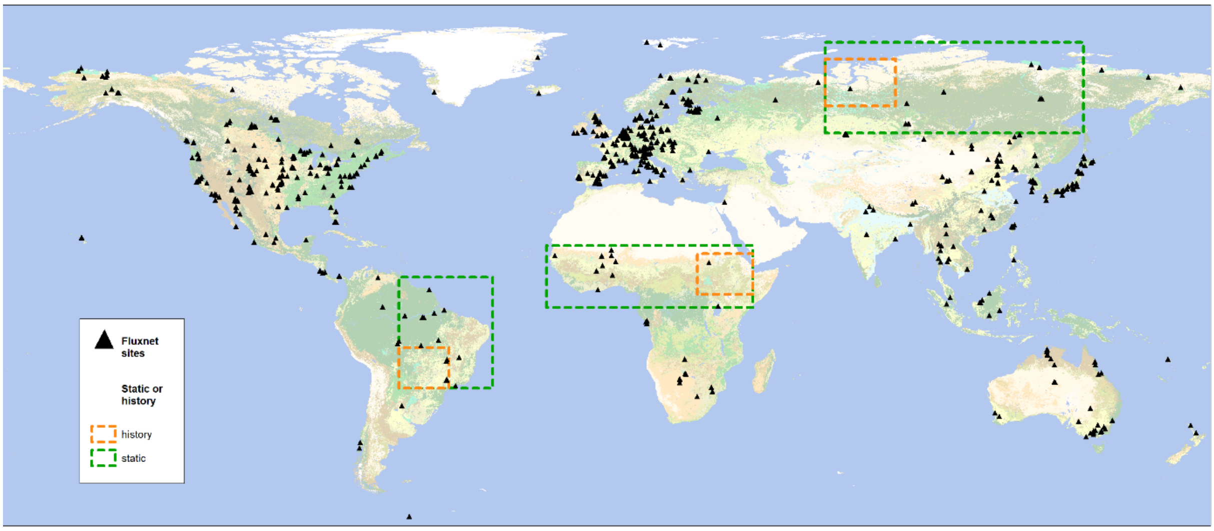


Figure 7. Final requirements for the location of the 3 study areas and Fluxnet sites (larger size image in Annex 6.6 , Figure 22).

5.2 Product classification system

5.2.1 First version

The first version of the classification system proposed (**LCCS approach upgraded to LCML/LCCS3**) at cycle 1 of the project by the consortium, seemed to be convenient for the climate users. Its **high compatibility with MRLC legend** (Annex 6.1) is a strong requirement because of the necessary merge that will have to be done to generate global maps. In addition, the LMCL system allows:

- to characterize geographical features and describe phenomena related to specific bio-geo-physical processes and people activities by the means of attributes which can be very valuable,
- and to better translate the LC classes in the Surface Functional Types used in climate models to describe processes and their feedbacks on water and carbon cycles.

Several deficiencies of the MRLC legend have been highlighted linked to the coarse spatial resolution. The major ones appear to be:

- The legend is not able to separate the different types of crops (row, summer/winter, permanent, orchards, /C3/C4, etc.), the irrigation type (flooded/sparkling), the multiple cropping systems (agroforestry types but also intercropping, number of cycles per year). Such features should be accessible with the HR images and could be notified with the LCML attributes. Given also that all the sparse/mixed classes should disappear, we expect a better characterization of the crop cultures under LCML system.
- The urban areas should also benefit from the HR and the LCML system. One class for urban areas being definitely not sufficient, it is important to separate (when possible) the different categories (buildings, roads, railways, trees, parks, lakes, etc...) and to give any information which could help to characterize surface roughness, which is an important parameter in land surface models, determinant in the quantification of surface heat and water fluxes.
- A single class for water bodies is also not sufficient, since it is important to separate thermokarst lakes in boreal regions to better characterize methane and carbon emissions, to separate wetlands (permanent/seasonal), rivers, etc... In permafrost regions, the specific landscapes characterizing the presence of permafrost like polygonal grounds, ice wedges, thermokarst formations, pingos, etc., could be valuable.

Finally, it has been highlighted that it is also important to characterize the horizontal organization for forests, shrubs, grasslands and crops, for example tiger bushes, row cropping, trees clumping for instance. Such features are determinant to model hydrological and biophysical processes and those features have a resolution compatible with the one of HR data.

The requirement for **LCML/LCCS3 classification system** is therefore very pertinent; the refinement of the attributes has been adjusted with the processing partners, regionally during the end of cycle 1 and beginning of cycle 2 of the project.

5.2.2 Second version

An agreement of a refined classification system was achieved after online and in person discussions (e.g. annual review meeting) with the participation of the EO Science team, Validation team and Climate team. The agreed classification system collects the demand of the climate modellers, the feasibility of the estimated EO skills classifiers and the provision and specifications of the samples for the validation procedures.

The current classification system is built as hierarchy system where some categories are split in different levels as shown in Table 1. This distribution is not regular and it is not applied to all main categories, for instance, the most distributed category is *croplands*, where relevant additional criteria (seasonality and irrigation) drives the sublevel classification. Additionally, the same criteria can drive a particular division on different levels, for example trees and shrubs do not follow the same level of organization for phenology and leaf type criteria. This hierarchy also responds to the rank of priorities considering the estimated classification and validation skills as well as the climate modelling needs. For example, the bare soil category was split in sands and rocks at the second level, which is a requirement from the climate modellers who want to better represent the infiltration properties of these two different surfaces and sand dust uprising for aerosols impacts modeling. In this rank, level 1 will be mandatory in all project results and the rest of levels will be generated depending on the particular application and following the levels priority.

LC CLASS							
CODE	**1st LEVEL**	**CODE**	**2nd LEVEL**	**CODE**	**3rd LEVEL**	**CODE**	**4th LEVEL**
10	Tree cover evergreen broadleaf						
20	Tree cover evergreen needleleaf						
30	Tree cover deciduous broadleaf						
40	Tree cover deciduous needleleaf						
50	Shrub cover evergreen	51	Broadleaf				
		52	Needleleaf				
60	Shrub cover deciduous	61	Broadleaf				
		62	Needleleaf				
70	Grasslands	71	Natural				
		72	Managed (pastures				
80	Croplands	81	Winter	811	Rainfed		
				812	Irrigated	8121	Sparkling
						8122	Flooding
		82	Summer	821	Rainfed		
				822	Irrigated	8221	Sparkling
						8222	Flooding
		83	Multicropping	831	Rainfed		
				832	Irrigated	8321	Sparkling
						8322	Flooding
90	Vegetation aquatic or regularly flooded						
100	Lichen and Mosses						
110	Bare areas	111	Unconsolidated	1111	Sands		
				1112	Bare soils		
		112	Consolidated				
120	Build-up	121	Buildings				
		122	Artificial Roads				
130	Open Water seasonal						
140	Open Water permanent						
150	Permanent snow and/or Glaciers	151	Snow				
		152	Glaciers				

Table 1: **New proposal for the LCCS classification system.**

A description of the main categories (level 1 and level 2) is provided in Table 3 and Table 4 at Annex 6.2.

5.2.3 Land cover changes definition

Based on the final legend definition, the main transition classes that are expected to be detected in the historical regions were analysed and defined. They are specific to the study region and therefore are summarized in Table 5 to Table 7.

On the south-western part of Amazonia, we expect to observe changes linked to deforestation, cropping, grazing and urbanisation. Since we are looking here to yearly transitions, we don't expect to detect some changes like bare soil or grasslands changing in adult trees for example, and we assumed that young trees will be classified in shrubs. Given also that in this region, needleleaf species, lichens and mosses, permanent snow and glaciers cannot be found, the possible transitions are listed in Table 4. As a result of the users consultations, the transitions which are the most interesting to study for the climate applications, are the transitions of forests into croplands, grasslands and urbans areas, which could be direct (if rapid) or indirect via the bare soil class. We think also that the evolution of wetlands and flooded areas could be interesting to look at, as a consequence of precipitation changes, such areas could see some evolutions other the last thirty years. At second level, the changes between natural and managed grasslands, as well as the changes of single cropping to multicropping could be valuable to identify.

On the eastern part of Sahel, we are still in a tropical climate but much dryer, the same land cover classes can be found but the expected changes are not the same. In this region, desertification, cropland extension, reforestation can be observed. There is also a large swamp area in South Soudan which is sensitive to drought and floods. Urbanisation increase is also visible in some areas. Therefore, we expect to detect the possible transitions listed in Table 5 and we highlighted the main transitions linked to crop extension, desertification and reforestation. At the second level, the transitions between crop species, managed and natural grasslands could be also valuable. In the urban areas, the extension of buildings over bare soils or other artificial surfaces could be also interesting to analyze.

Finally, in western Siberia, with a very different climate, the land cover classes are not the same, the evergreen broadleaf species are not present as well as the vegetation flooded. We expect all the other classes except the permanent snow and glaciers, because this region is not mountainous. Concerning the yearly changes, they should be linked to vegetation greening because of climate warming (transitions between shrubs and trees, grasslands and shrubs , lichens/mosses and grasslands from south to northern latitudes), croplands abandonment or extension, and as a consequence of permafrost thawing, the increase of seasonal and permanent open water bodies. These transitions are listed in Table 6, the main transitions highlighted concern the impacts of permafrost thawing and climate warming on the vegetation. At the second level, we could be interested to the transitions between winter to summer crops and the conversion of natural to managed grasslands.

5.3 Coverage period

The coverage period **(1990 – 2019)** is satisfactory, with the year **2019** chosen for the static map. The 5-year mean LC maps are sufficient for climate studies if the changes are provided yearly. The consistency of the changes should be checked, along with the side products so that the climate modelling groups could assimilate coherently different sources of information on surface cover and surface state.

5.4 Side products needed

The list of side products that could be beneficial for the climate modelling teams could be large and varies between the groups. We list below the main products that were identified:

- Seasonal products of the **Vegetation Activity** like EVI / NDVI or fluorescence indices, on a pixel basis for the year 2019 of the static map. These products should be coherent with the vegetation cover and are either used as input or as validation-data by the different climate modelling groups.
- Seasonal variation of hydrological variables such as **snow cover** and **water extent**, on a pixel basis for year 2019 on the static region are also crucial, **burnt areas** as provided in the MRLC project are also very

valuable.

- For the LCC time series (over the smaller domain), including **mean and standard deviation** over the 30-year period of the above products would also be helpful.
- The access to auxiliary products at the same resolution and/or re-gridded in the same projection/grid would be clearly very valuable: information related to **topography, aspects, albedo, LAI**, etc., for example, would help the use of the HRLC products in climate studies.

5.5 Post-processing tools

The climate modelling groups are not directly using the satellite land cover types from the LCCS classification but rather Plant or Surface Functional Types (PFT/SFT), which are the basic units of most models. In order to map the LCCS classification to PFT/SFT, a specific free ad-hoc tool was designed during the MRLC project. We thus propose to use such tools that contain:

- A **"cross-walking" table** that describes the fraction of PFT/SFT associated to the different LCCS classes, using expert knowledge. We will use in particular the HRLC data to refine such table for the global MRLC mapping, given that key information on the mixed LC classes will be provided by the HRLC maps to better define the PFT/SFT fractions.
- A **re-mapping facility** that allows to map the resulting PFT/SFT (and the original LCCS classes) onto an ensemble of pre-defined grids (regular in latitude and longitude but also Gaussian).

We thus propose to use such post-processing tools for the transformation of the HRLC map into PFT/SFT with possibly minor adjustment to the tool (adding new grids suitable to the three regions of interests). The HR LC and LCC will thus be re-mapped on generic PFT/SFT that were defined across three EU climate modelling teams. Such classification, proposed in the MRLC project (the different generic PFTs), can be viewed under: https://orchidas.lsce.ipsl.fr/dev/lccci/generic_pft.php. The participants of the user virtual meeting expressed their interest to obtain these generic PFT/SFT; the LSCE partner will thus produce them with the cross-walking tool and make them available for the groups that do not want to run the tool.

Additionally, the LSCE proposes to provide additional post-processing of the generic PFTs. They are linked to:

- The **separation of C3 versus C4** photosynthetic pathway for grassland. This distinction is crucial for most climate/land surface modelling teams. We propose to use a C3:C4 ratio global product (static map) defined by a US team combining model information and satellite observations [4].
- The inclusion of **land-sea mask** to separate sea water from inland water.
- Possible split of the PFT/SFT according to different **climate regions** following the Koppen-Geiger classification [5].

Both, the results of these post-processing steps as well as the associated tools will be provided to the user community.

5.6 Products format

The preferred product formats for the data are **GeoTIFF and NetCDF**. For metadata are: **TXT and XML**. The TXT format could be an ambiguous answer and it could include a wide range of non-structured and very flexible format, but very difficult to harmonize and automatize. XML is the other preference; it is a standard format and widely implemented in GIS and RS software.

5.7 Uncertainties characterization

Two types of quality information are suggested: **thematic and spatial**. The first one refers to provide the classification results for the most likely class and secondary class. The second one indicates that some global statistical error indicators are not enough, some users need spatialized pixel level quality information.

5.8 Enrolment of CMC

The Climate Research Community has expressed its strong interest in the future HRLC and their requirements concerning region location, classification system, metadata provided, etc., have been accounted for as much as possible in the product specifications. This is probably not enough to enrol them in the product assessment work because they have not been funded for that. However, they express their intention to use the products when those will be available for their study region and we expect some feedbacks afterwards. The MPI and Met Office teams which are involved in the MRLC follow-on project should be able to find a way to collaborate with LSCE in this framework. The next user meeting, where LSCE will show its first results, will be decisive on that point. Besides, within the ORCHIDEE community, we have already advertised on the future products and we expect to work with N. De Noblet and Y. Balkanski at LSCE, on the Sahelian region. They are indeed interested to work respectively, on the vegetation/climate feedbacks linked to the reforestation projects like the Green wall at the northern limit of Sahel with Sahara, and on the modelling of dust emissions and the foreseen improvements of source location and roughness characterization with the HRLC products.

6 Annex

6.1 MRLC legend

The MRLC legend is the following:

VALUE	LABEL
0	No Data
10	Cropland, rainfed
20	Cropland, irrigated or post-flooding
30	Mosaic cropland (>50%) / natural vegetation (tree, shrub, herbaceous cover) (<50%)
40	Mosaic natural vegetation (tree, shrub, herbaceous cover) (>50%) / cropland (<50%)
50	Tree cover, broadleaved, evergreen, closed to open (>15%)
60	Tree cover, broadleaved, deciduous, closed to open (>15%)
70	Tree cover, needleleaved, evergreen, closed to open (>15%)
80	Tree cover, needleleaved, deciduous, closed to open (>15%)
90	Tree cover, mixed leaf type (broadleaved and needleleaved)
100	Mosaic tree and shrub (>50%) / herbaceous cover (<50%)
110	Mosaic herbaceous cover (>50%) / tree and shrub (<50%)
120	Shrubland
130	Grassland
140	Lichens and mosses
150	Sparse vegetation (tree, shrub, herbaceous cover) (<15%)
160	Tree cover, flooded, fresh or brakish water
170	Tree cover, flooded, saline water
180	Shrub or herbaceous cover, flooded, fresh/saline/brakish water
190	Urban areas
200	Bare areas
210	Water bodies
220	Permanent snow and ice

Table 2: **MRLC legend based on LCCS classification system.**

6.2 Description of the main HRLC classes

6.2.1 Level 1:

LC class	Description

Tree cover evergreen broadleaf	Primarily vegetated areas with a tree canopy cover of more than 50 % at the time of fullest development. Snow and/or ice, open water or built-up areas cover less than 50% of the area. A tree is a woody, perennial plant with a simple and well-defined stem, bearing a more or less defined crown [6] and a minimum height of 5 m. Tree canopy cover composed of trees that are never entirely without green foliage [6]. Trees are broadleaved and come from the Angiospermae group.
Tree cover evergreen needleleaf	Primarily vegetated areas with a tree canopy cover of more than 50 % at the time of fullest development. A tree is a woody, perennial plant with a simple and well-defined stem, bearing a more or less defined crown [6] and a minimum height of 5 m. Tree canopy cover composed of trees that are never entirely without green foliage [6]. Trees carry typical needle-shaped leaves and come from the Gymnospermae group.
Tree cover deciduous broadleaf	Primarily vegetated areas with a tree canopy cover of more than 50 % at the time of fullest development. Snow and/or ice, open water or built-up areas cover less than 50% of the area. A tree is a woody, perennial plant with a simple and well-defined stem, bearing a more or less defined crown [6] and a minimum height of 5 m. Tree canopy cover composed of trees that are leafless for a certain period during the year [6]. Trees are broadleaved and come from the Angiospermae group.
Tree cover deciduous needleleaf	Primarily vegetated areas with a tree canopy cover of more than 50 % at the time of fullest development. Snow and/or ice, open water or built-up areas cover less than 50% of the area. A tree is a woody, perennial plant with a simple and well-defined stem, bearing a more or less defined crown [6] and a minimum height of 5 m. Tree canopy cover composed of trees that are leafless for a certain period during the year [6]. Trees carry typical needle-shaped leaves and come from the Gymnospermae group.
Shrub cover evergreen	Primarily vegetated areas with a shrub canopy cover of more than 50 % at the time of fullest development. Snow and/or ice, open water or built-up areas cover less than 50% of the area. A shrub is a woody perennial plant with persistent woody stems and without any defined main stem [6], being less than 5 m tall. Shrub canopy cover composed of shrubs that are never entirely without green foliage [6].
Shrub cover deciduous	Primarily vegetated areas with a shrub canopy cover of more than 50 % at the time of fullest development. Snow and/or ice, open water or built-up areas cover less than 50% of the area. A shrub is a woody perennial plant with persistent woody stems and without any defined main stem [6], being less than 5 m tall. shrub canopy cover composed of shrubs that are leafless for a certain period during the year [6]
Grassland	Primarily vegetated areas with an herbaceous cover of more than 50% at the time of fullest development. Snow and/or ice, open water or built-up areas cover less than 50% of the surface. Herbaceous plants are defined as plants without persistent stem or shoots above ground and lacking definite firm structure [7].
Croplands	Primarily vegetated areas with a herbaceous cover of more than 50 % at the time of fullest development. Snow and/or ice, open water or built-up areas cover less than 50%. Croplands are mainly herbaceous plants are sowed/planted and harvestable at least once within the 12 months after the sowing/planting date. Herbaceous plants are defined as plants without persistent stem or shoots above ground and lacking definite firm structure [7]. Cropland includes rain fed crops, irrigated crops, aquatic crops and annual pastures. It is an adaptation of the Joint

	Experiment for Crop Assessment and Monitoring (JECAM) cropland definition (JECAM 2014). Croplands exclude permanent crops like woody plantations that are part of the tree or shrub classes.
Vegetation aquatic or regularly flooded	Primarily vegetated areas with trees, shrubs, grasslands or lichens and mosses covering more than 50 % of the area flooded by water for more than 4 months throughout the year. The water can be saline, fresh or brackish.
Lichen and mosses	Primarily vegetated areas with a cover of more than 50% at the time of fullest development. Snow and/or ice, open water or built-up areas cover less than 50% of the surface. Mosses are a group of photo-autotrophic land plants without true leaves, stems or roots [8]. Lichens are composite organisms formed from the symbiotic association of fungi and algae [8].
Bare areas	Areas where the sum of vegetation cover is less than 50% at the time of fullest development. Snow and/or ice, open water or built-up areas cover less than 50% of the surface. Bare rock areas, sands and deserts are classified as bare areas. Extraction sites (open mines and quarries) and salt flats covered by water for less than 5 months are classified as bare areas.
Built-up	Areas where any predominant type of linear and non-linear artificial surface covers at least 50%. Snow and/or ice, and open water cover less than 50% of the surface. Built-up areas include buildings, roads, airports, greenhouses, etc. but may, however, exclude temporary settlements.
Open Water seasonal	Areas where open water covers at least 50% of the surface and remains between 5 and 9 months a year, except in special circumstances (particularly dry year, construction of dams, etc.). Snow and/or ice and built-up areas cover less than 50% of the surface. Water bodies can be natural or artificial. Water can be saline, fresh or brackish.
Open Water permanent	Areas where open water covers at least 50% of the surface and remains for more than 9 months a year, except in special circumstances (particularly dry year, construction of dams, etc.). Snow and/or ice and built-up areas cover less than 50% of the surface. Water bodies can be natural or artificial. Water can be saline, fresh or brackish.
Snow and/or Ice	Areas where snow and/or ice cover at least 50% of the surface for more than 9 months a year. Built-up areas and open water cover less than 50% of the surface.

Table 3: **Description of the first level categories of the HRLC updated legend**

6.2.2 Level 2

LC class	Description
Shrub cover evergreen broadleaf	The evergreen shrubs are broadleaved and come from the Angiospermae group.

Shrub cover evergreen needleleaf	The evergreen shrub cover is composed of shrubs carrying typical needle-shaped leaves (Gymnospermae group) that are never entirely without green foliage [6]
Shrub cover deciduous broadleaf	The deciduous shrub cover is composed of broadleaved shrubs coming from the Angiospermae group.
Shrub cover deciduous needleleaf	The deciduous shrub cover is composed of shrubs carrying typical needle-shaped leaves (Gymnospermae group) that are never entirely without green foliage [6]
Natural grassland	Herbaceous areas not planted by humans but that can be influenced by human actions to some extent. Generally, low yields and high biodiversity value natural or semi-natural herbaceous covers can be grazed extensively (Velthof et al. 2014)
Managed grassland (pastures)	Herbaceous areas sowed/planted by humans and that are sowed and planted at least twice a year
Winter crops	Sowed/planted herbaceous areas present at spring time
Summer crops	Sowed/planted herbaceous cover not present before spring time
Multicropping	Several crop cycles a year.
Unconsolidated bare areas	Bare areas with an unconsolidated aspect (e.g. bare soil, sands)
Consolidated bare areas	Bare areas with a consolidated aspect (e.g. made of rocks, hard pans)
Buildings	Built-up areas where buildings cover at least 50% of the surface
Artificial roads	Built-up areas where roads cover at least 50% of the surface
Snow	Permanent snow
Glaciers	A glacier is defined as a perennial mass of ice, and possibly firn and snow, originating on the land surface from the recrystallization of snow or other forms of solid precipitation and showing evidence of past or present flow

Table 4: **Description of the second level categories of the HRLC updated legend**

6.2.3 Level 3

At third level, we add the rainfed and irrigated classes for the 3 crop categories, which can be defined as follows:

Rainfed	**Sowed/planted herbaceous areas that are harvestable at least once within the 12 months after the sowing/planting date that depends on rainfall to grow**
Irrigated	Sowed/planted herbaceous areas that are harvestable at least once within the 12 months after the sowing/planting date that depends on artificial water supply to grow

6.2.4 Level 4

And at fourth level, the type of irrigation could be specified between sparkling and flooding categories, as defined below:

Sparkling	**In sprinkler or overhead irrigation, water is piped to one or more central locations within the field and distributed by overhead high-pressure sprinklers or guns.**
Flooding	In surface (flood, or level basin) irrigation systems, water moves across the surface of an agricultural lands, in order to wet it and infiltrate into the soil.

6.3 Description of the main LC changes

The main land cover changes on the Amazonian, African and Siberian regions are the following:

Year N	EBT 10	ENT 20	DBT 30	DNT 40	ShrE 50	ShrD 60	Grass 70	Crops 80	Flood 90	Li&Mo 100	Bare 110	Built 120	OpWs 130	OpWp 140	Sn&Ic 150
Year(N+1)															
10					X							X			
20															
30						X						X			
40															
50	X		X				X	X	X		XX	X			
60							X	X	X		XX	X			
70	X		X		X	X		X	X		XX	X			
80	XX		XX		XX	XX	XX		X		XX	X			
90	X		X		X	X	X	X							
100															
110	X		X		X	X	X	X				X			
120	XX		XX		XX	XX	XX	XX			XX				
130												X		X	
140													X		
150															

Table 5: **Transition classes expected on the Amazonian historical region (SW part of Amazonia). Double crosses indicate the transitions which should require more attention from the climate modellers point of view.**

Year N	EBT 10	ENT 20	DBT 30	DNT 40	ShrE 50	ShrD 60	Grass 70	Crops 80	Flood 90	Li&Mo 100	Bare 110	Built 120	OpWs 130	OpWp 140	Sn&Ic 150
YearN+1															

10					X		X	X				X			
20															
30						X	X	X				X			
40															
50	X		X								X X	X			
60	X		X								X X	X			
70	X		X		X	X		X			X X	X			
80	X X		X X		X X	X X	X X				X X	X			
90													X		
100															
110	X X		X X		X X	X X	X X	X X							
120	X X		X X		X X	X X	X	X			X X				
130									X					X	
140									X				X		
150															

Table 6: **Transition classes expected on the African historical region (Ethiopia). Double Crosses indicate the transitions which should require more attention from the climate modellers point of view.**

Year N	EBT 10	ENT 20	DBT 30	DNT 40	ShrE 50	ShrD 60	Grass 70	Crops 80	Flood 90	Li&Mo 100	Bare 110	Built 120	OpWs 130	OpWp 140	Sn&Ic 150
YearN+1															
10															
20					X X										
30															
40						X X									
50		X	X	X			X X	X		X					
60		X	X	X			X X	X		X					
70		X	X	X	X	X		X X		X X	X	X			
80		X	X	X	X	X	X								
90															
100															
110		X	X	X	X	X	X	X				X			
120		X	X	X	X	X	X	X							
130					X X	X X	X X	X X			X X			X X	

140													X X		
150															

Table 7: **Transition classes expected on the Siberian historical region (Western Siberia). Double Crosses indicate the transitions which should require more attention from the climate modellers point of view.**

6.4 Detailed responses to the user survey

The following table collects the affiliation of the participants to the survey

Melnikov Permafrost Institute	ECMWF
University of Alberta	Barcelona Supercompunting Center
leiden university	CNRS
University of Extremadura	LMU Univ. Munich, Germany
Met Office Hadley Centre	CNRM - Université de Toulouse, Météo-France/CNRS
CESBIO - INRA	CNRM, Météo-France
Helmholtz Zentrum Geesthacht / Alfred Wegener Institute	University of Leeds
b.geos	Ural Federal University
University of Zurich	Institute of Industrial Ecology, Ural Branch Russian Academy of Sciences
PhD student. Department of Graphic Expression, Universidad de Extremadura, Cáceres.	Arctic research station of Institute of Plant and Animal Ecology Ural Branch Russian academy of Sciences
UAB	Universitat Autònoma de Barcelona
vmc, Antsiranana	University of Edinburgh
BSC	WWF-US
University of Alaska Fairbanks	University of Illinois, Urbana-Champaign
University of Hawaii at Manoa	Indiana University
Thuenen Institut of Forest Ecosystems	FAO of the UN
LEGOS-OMP	University of Buenos Aires - CONICET

Table 8: **List of affiliations of participants in double column. The order doesn't correspond to the following tables.**

6.4.1 On the choice of the study regions

- *What are your advices on the pre-selected regions (requirements for the precise location and spatial extent of the studied regions)?*

Please get data for ALTRES (Amazon Liana and Tree Remote Sensing) experiment in Tapajos.
I understand the choice for Siberia from a climate change point of view, but: information and understanding of Siberia is much more limited than for instance for the European (sub-)arctic region, with much more ground truth data (amongst others, some of my projects). Moreover, it may be strategically smart to have an European region as well, instead of in Russia where ground trothing is a real issue. Alternatively, the Canadian arctic might be an option. A number of remote sensing with ground trothing projects run in the Canadian Arctic
Given the importance of large and expanding urban areas for accommodating and often increasing the vulnerability of a significant fraction of people (in both developing and developed countries) these should be one of the foci of the work.
northern high latitudes underlined by permafrost
Covering as much as diversity (in land cover types) as possible
we need all permafrost areas covered, otherwise it can be only used to assess quality of global maps
Due to the acceleration of the hydrological cycle in the Arctic, it would be great having more information in other Arctic regions besides the boreal part of Siberia, such as Alaska, Greenland, Canada or Finland
I wonder if the north boundary of the Amazon region can be moved further north to include more forests.

Very good. They cover different types of land cover.
For dust modeling, it would be important to cover also sparse vegetation around dust source area. Ideally, we would need a global dataset. With regard to the three pre-selected regions, our suggestion would be to extend the Sahel-area somewhat further north to cover vegetation cover and its fluctuation at the southern fringes of the Sahara.
global coverage would be perfect
The preselected study region would be best suited if they can represent the typical modelling patches or tiles that are used in the modelling world. One of the big challenge in modelling is to know if the Earth surface fluxes partitioning is correctly represented since all insitu data tend to represent aggregated fluxes or atmospheric mixed quantities. The choice of regions that are across a vegetation gradient for instance can be well adapted to advance the science and model development at Km scale.
west africa
I am extremely interested in the land cover and changes over western Ethiopia and South Sudan.
Target most dificult as opposed to low-hainging fruit areas
South and South Asia (SSEA)
I suggest to include the Gran Chaco area in South America. The actual selection do not include areas in Paraguay and Argentina where huge land use change occurred during the last decades. I suggest to include this area southward to the actual selection.
Amazon & pan-tropics; semi-arid biomes (savannas)
I am most familiar with the African region, and the overall boxed region looks good. However, I'm surprised there is not a box co-located with the AMMA-CATCH region further to the west.
And South Asia ?
High resolution data from these regions, particularly the Amazon, would be very useful
I would like the region in Siberia to be extended to the west so as to include the entire Yamalo-Nenets Autonomous District in the Russian Federation.
North-west Siberia (Yamal-Nenets autonomous district)

Table 9: **Complete list of the responses to preliminary study regions.**

- *Are you involved in projects focused on these regions that would benefit from HRLC data?*
- *Would you be interested to work on other regions for which, land cover and climate have already shown strong links? If YES, which ones?*

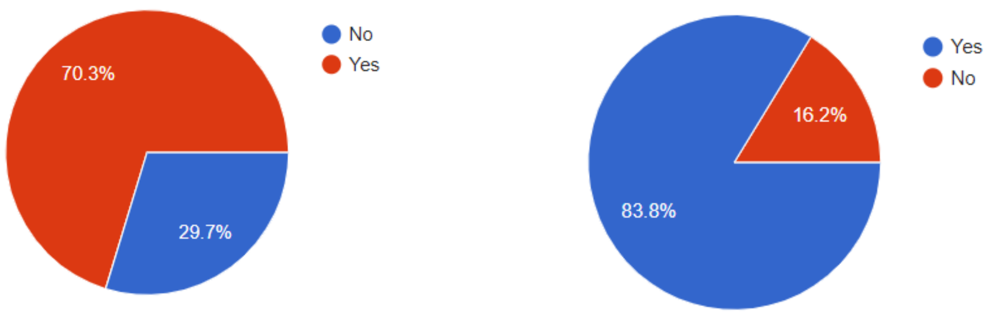


Figure 8: Involvement in projects focused on the preliminary regions (left), interest in other regions (right).

Amazon, as long it cover the sites where we are conducting work with liana removal experiments. I have not hear about the sites yet in the Amazon. Also, why the santa rosa national park in Costa Rica was not selected, it ranked 4 in the world and it is the perfect site for this kind of studies.
the mediterranean
Urban areas as noted in the comments above.
South of France
Amazon, Tibetan Plateau
I expect rather homogenuous landscapes in the three study regions. Did you consider adding a fragmented anthropogenic landscape as well? This could be an interesting test case to challenge the capability of climate models to

deal sub-pixel heterogeneity.
The Mediterranean Basin
temperate, tropics, tundra
Spain
Mediterranean regions
we work over all Permafrost Areas, globally
Madagascar
Indonesia
Mediterranean, boreal forest and Arctic regions
I wonder if you can include southeast U.S. (Alabama, Mississippi,Louisiana) and northwest U.S. where forests have been intensively managed.
Europe/ Germany
Mekong Basin
In particular dust source regions are of strong interest for us.
If not global the Africa, Boreal zone, Europe
The regions identified in the work of Koster et al 2010, and the region that are currently studied by the GHP panel of GEWEX/WCRP can be of interest. A success of the initiative may come from overlap with existing regional initiatives for which there is momentum (e.g. PANNEX, selected subdomains of Hymex).
Amazon basin and Siberia
Rest of the SSEA
Southwestern USA
Africa, South East Asia, Latin America
As I suggested previously, the Gran Chaco area, where humid and semiarid forest are being significantly modified.
Boreal eurasia
The Ebro basin in NE Spain. I am organizing a field campaigne there for summer, 2020.
The entire world
Yamal peninsula and the territory of the Yamalo-Nenets Autonomous District of Russian Federation
Yamal Peninsula, the coast and islands of the seas of the Arctic Ocean
Siberia
Iberian Peninsula
Rest of the SSEA

Table 10: Complete list of the responses to interested regions with strong research links.

6.4.2 On the spatial resolution

- *Please, indicate your needs in spatial resolution:*

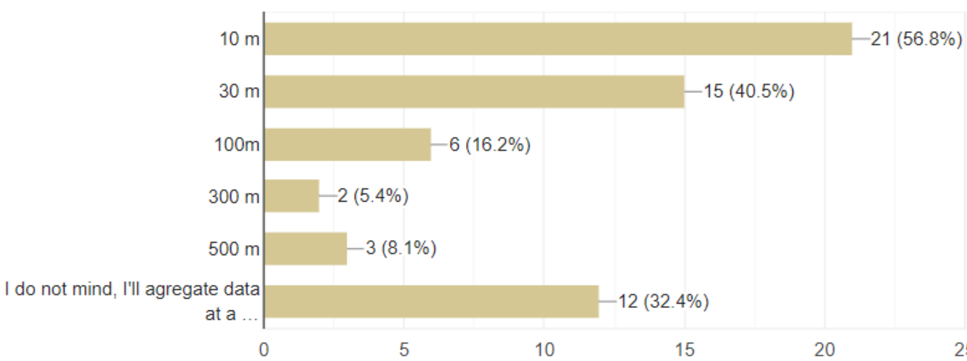


Figure 9: Needs of spatial resolution.

- *How will you use a static map at 10 m resolution for 2017 and 30 m resolution for the 5-year land cover change products?*

to look at changes on liana communities associated to their removal.
I would use it to much better constrain land surface variables for which I would need land cover type information to constrain solution space.
To define fractional land-cover types in a km-scale (convection permitting) limited area regional climate model
Assess changes and trends at larger scale. Zoom at full scale for finer analysis.
We have a project (SODEEP – Study of the development of extreme events over permafrost areas https://www.hzg.de/science/eu_projects/h2020/earth/078499/index.php.en) with an aim to improve permafrost processes presentation in the climate models. Therefore, introducing the Land Cover class such us landform indicative of permafrost, would be the most beneficial for us. Static map would be used for evaluation, and 5-year land cover change map, eventually to see evolution of thermokarst lakes and landforms (indicative of permafrost).
Something we are trying now is to use high resolution data to determine whether an observational site could be considered representative for model evaluation. High resolution data could be used to calculate landscape heterogenity/entropy which in turn could be used to refine the parameterization of for example roughness length.
To assess vegetation change and, in particular, to detect episodes of forest mortality
parametrization of DGVMs
To analyze in detail the coverage in 2007 and be able to track the changes.
impact in C cycle
visual assessment of locations of in situ records
10 m for inventory and 30 m for monitoring LULC
I would degrade the spatial resolution from 10 m to 30 m and I would compare what has changed
Improve biomass mapping
Correlation to our long-term forest monitoring to detect abiotic/ biotic damages
Aggregationg the data
downscaling
I will aggregate the map to 1/120 of a degree (30 arc second) as this is the input resolution of the global interpolation software we currently use at ECMWF.
For mapping of permafrost landscapes map
dust emission modellling, water cycle
I will very likely analyze only a subset of the data.
10m data should inform condition of data at 30m (not replace)
I am interested in understanding the socioeconomic and biophysical drivers of LULCC at local, country and regional scale using these maps. For our analysis it is not necessary to use 10 m resolution data. 10 m resolution data may be important for the evaluation purpose, but not for our analysis purpose
Investigate possibility to characterize sparsely vegetated and spatially heterogeneous ecosystems and track woody plant encroachment
national area statistics
impacts of land cover change on hydrology and carbon uptake
ASsess forest degradation; combine with satellite data (SENTINEL) to identify forest biotic disturbances (e.g. areas affected by pests)
30 m resolution for 5-year LC data would allow more accurate determination of the climate impact of these land cover changes. At 10 m resolution one may be able to draw more detailed information about the composition of the forest cover, for example
I'm going to develop and validate the model of methane emission from this area.
To see the changes in willow thickets spatial distribution and density

Table 11: **Complete list of the uses of LC and LCC maps.**

- *How will you take benefit of the increased spatial resolution compared to Medium Resolution products (300 m)?*

No, our experiment is of high resolution and the higher resolution the better.
Better constrained solutions for land surface variables
Accuracy Enhancement for Land Cover Classification

To provide more accurate descriptions of the land surface for km-scale climate modelling for use in model prediction, evaluation and tuning studies.
300 m is too coarse for my actual research.
Landforms indicative of permafrost are on the 10 m scale or even smaller, therefore I some features interesting for the project that I am working on are not present at Land Cover map at all.
I would consider resolutions below 100m as disruptive for how we used LC data in the past. The first example given in the previous question is not possible with 300 m data (because the observational sites are typically much smaller). The second example could be tried with 300m data.
It will allow better identification of forest mortality and facilitate attribution of its causes
more detailed radiative transfer scheme of vegetation types
To obtain more accurate maps
Tundra is very heterogenous, 300m is not adequate
for local planning multisectorial integration
With higher spatial resolution it will be easy tom compare with other surface energy balance products at similar spatial resolutions to understand the change in energy balance partitioning linked to land cover change
possibility to correlate to visual ground assessment/ up-scaling from UAV
Through a better definition of study areas
At the moment we aggregate the maps to our model resolution and thereby benefit only from the increased-accuracy of the aggregated resolution. To really take benefit of the increased resolution we would have to develop new methods.
better understanding of land use
High resolution is very important for static maps such as water bodies and for defining land/cover as percentage at 1km. We know that at 1km (30 arc seconds) very few pixels will have a pure biome, therefore it would be good to have 1km maps as % of biome coming from higher resolution maps. Similarly for water bodies and anthropogenic surface areas (human settlement and irrigated areas).
For zonation of permafrost landscapes
10 m is suited to cropland
The 10m data can infrom the 300m.
For evaluation purpose
Hopefully this will help track change in spatially heterogeneous and sparse vegetation semi-arid ecosystems
better classification
Better resolution would reduce noises produce by borders and mixed pixels.
Better match between LC and satellite data; better assessment of forest degradation/logging and other human interference.
Over the Ebro, the agricultural field scale is typically (approximately) 100m, thus this spatial scale interests me. Obviously it would be more accurate to use 30 or even 10 m products, but I can not confirm that I would actually use such high resolution data, although someone within the project might.
Higher resolution data allows more accurate calculation of changes to the surface energy fluxes - this is not really possible at 300 m
Increased spatial resolution will help better distinguish different types of soils and plant communities.
Because most of willows patches are a way smaller than 300 m

Table 12: **Complete list of the expected benefits on HR products.**

6.4.3 On the temporal resolution and extent

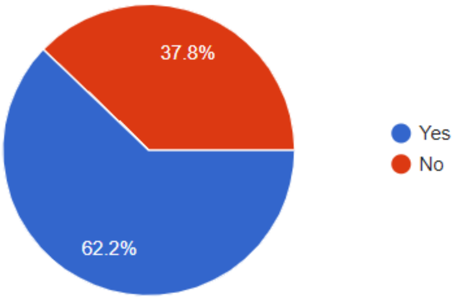
- *Are 5-year land cover change maps already valuable for your application? If NO, could you indicate your preferred temporal frequency?*

It will be good every 6-months.
Lifespan and evolution of thermokarst lakes is from 10 to 100 years, therefore as long as possible period would be better, 10 to 30 years
Although of course more frequent products (e.g., yearly) would be better
but would be better finer frequency - especially for disturbances
seasonality makes annual classifications inadequate, there is consensus for the Arctic that trends using all acquisitions available is better (see e.g. works by Nitze et al.)
a 3 years frequency preferred

1 year will be even better
For dust application we would be interested in seasonal changes in land cover.
given the large effort 5-year steps is excellent. However for maximum user uptake could be better to have yearly output, even if the 5-year might be the underlying processing step (in modelling is preferred to have yearly small updates than 5-yearly bigger jumps).
Annual.
Yearly or bi-anual data as required for example for REDD+
annual
1year
Annual
In fact, I do not know (I was obliged to answer): see next response
Would be better to get 30-50 years changes!

Table 13: **Complete list of the preferred temporal frequency.**

- *Is the time period (1992-2017) already valuable for your applications? If NO, what are your needs in temporal extent?*



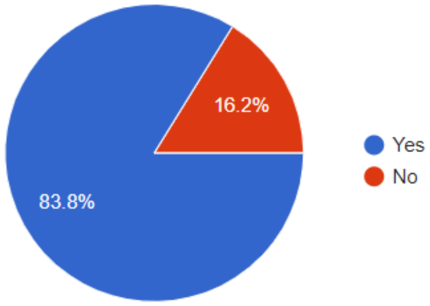


Figure 10: Agreement with the 5 year change period (left), and agreement on the time period 1992-2017 (right).

50 years for the classic applications. Nevertheless, 1992 almost includes 1990 which is the reference for carbon accounting within the Kyoto Protocol and the Paris Agreement. 1989 would be slightly better.
extending to landsat era would even be more valid
maximum 5 years temporal extent
Landsat-TM satellite series started in 1984 with s spatial resolution of 30 m. It would be great if the time series could start in 1984
However, the longer the record, the better - as always.
Given that technological capability the 5-year effort could start considering the most recent period first. That would provide a solid background to update past periods using what is available.
Annual
As long as possible
I will be doing mesoscale atmospheric model simulations for less than a single annual cycle, however, some of my colleagues will be doing longer simulations (hydrological modeling) so LCC data from 1992-2017 (and perhaps to 2020 eventually) might be of interest to them. But I can not answer this question on thier behalf. However, it would be of great interest to have an up to date (for 2020!) high resolution irrigation map over the Ebro basin.
It should interesting to cover a larger period for climate application, at least 1979-2017... and even more interesting 1900-2017
1950-2018

Table 14: **Complete list of the preferred time period**

6.4.4 On the product classification system and delivery formats (including documentation)

- *Is the FAO LCCS classification system for land cover adapted for your foreseen uses?*

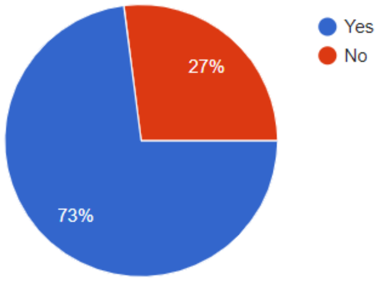


Figure 11: Agreement with FAO LCCS categories.

- *Which other one would you prefer?*
  i. Vegetation related requests:
     1. Evergreen and deciduous forest categories
     2. Phenology classes, specially shrub classes
     3. CAVM – Circumpolar Arctic Vegetation Map or Globpermafrost
  ii. Water or soil related requests:
     1. FAO-LCCS but with adaptation for hydrologic purposes
     2. thermokarst lakes category
     3. other landforms indicative of permafrost's
  iii. Urban related requests:
     1. More than one class for urban categories

- *Which formats would you like the products to be delivered?*

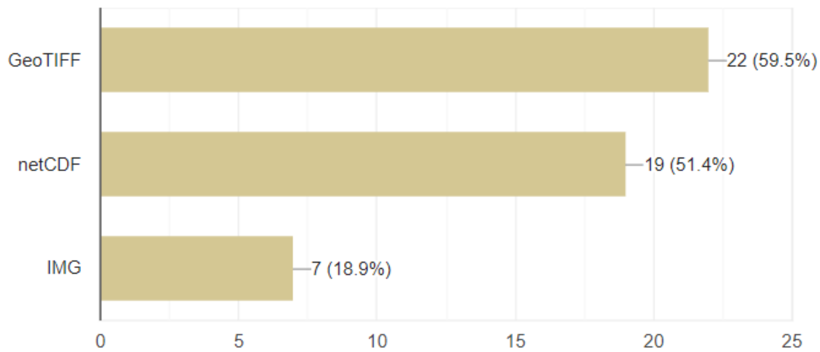


Figure 12: Formats for the product classification system

- *Which minimum size (tile surface) would you like to be available for downloading?*

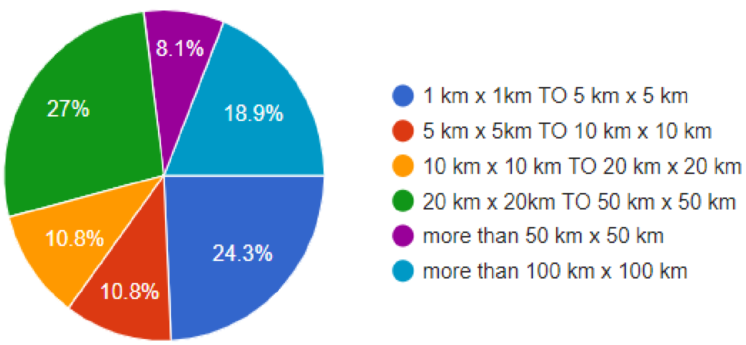


Figure 13: Proposed Tile dimensions

- *Which format would you like the metadata to be delivered?*

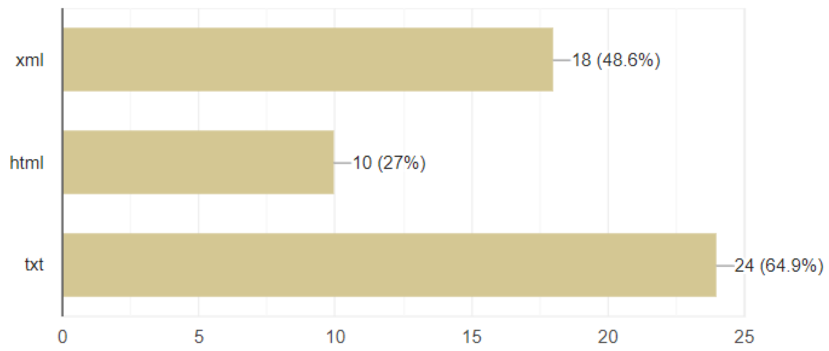


Figure 14: Proposed metadata formats.

6.4.5 On the side products

- *Which side products would be the most relevant for your studies? If OTHERS, please indicate which ones*

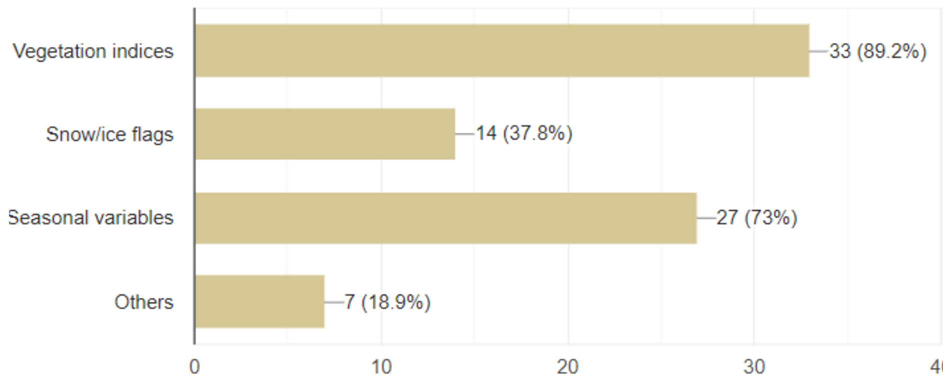


Figure 15: Side products demand

stratification in ecoregions
Thermokarst lakes, and eventually landforms indicative of permafrost
Soil indices
land surface temperature, albedo
Accuracy of the assessment (within the metadata) per pixel
any additional vegetation information (photosynthetic and non-photosynthetic).
A large efforts is going into LUC interconsistency therefore information that can help identify inconsistencies will be important (e.g. vegetation and water co-exiting in a pixel? Is it a sign of irrigation practices or flood plain?)
Permafrost landscapes dynamics
Yearly pixel level statistics (mean, median, quartiles, SD, VAR, etc...
Seasonal variables
irrigation maps, soil moisture products, LST

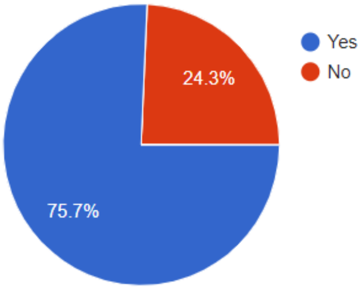
Table 15: **Complete list of additional side products**

6.4.6 On the post-processing tools

- *Are the tools developed in MRLC satisfactory for you (the tool to map the original 300 m resolution LC at lower resolution and to split LCCS into user-defined classes)?*
- *Which facilities would you suggest to add?*

Any interesting answer.

- *Are the pre-defined output grids enough?*



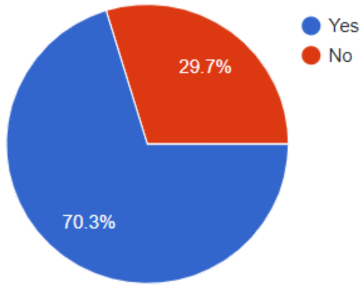


Figure 16: Satisfaction on the MRLC developed tools (left), and agreement on the pre-defined output grids (right).

- *If NO, which ones would you define?*
- *Do you wish to have viewing capabilities of LC changes?*

Several responses are similar than “Do not have sufficient experience with these to comment”. The rest are:

In regional climate modelling rotated grid is used, therefore it will be useful to have possibility to project data on the rotated pole regional grid
don't know them in detail, but flexibility is a necessity: imagine none of them matches an ESM model grid? Would be better that the aggregations would support it. Perhaps you also allow uploading a grid with coordinate system information?
T255 and T511, these are climate grids used by IFS model
10m

Table 16: **Complete list of suggestions for the capabilities of the post-processing tools.**

6.4.7 On the uncertainties

- *Would these uncertainties be sufficient? If NO, what would you need?*

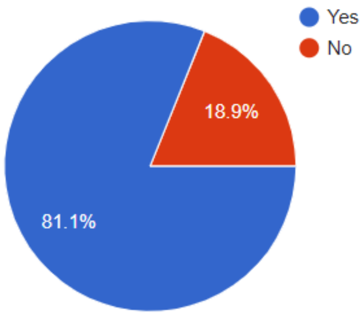


Figure 17: Agreement with the initial proposal of uncertainty information.

quantitative uncertainties
Probabilistic membership
perhaps also the confidence in the classification itself
per pixel/ raster information
Statistically inferred uncertainty for area estimates
Per pixel uncertainty classes

Table 17: **Complete list of needed uncertainty information.**

- *How will you use uncertainty information in your studies?*

to look at changes on liana communities
to constrain my estimates of land surface variables
to take them into account if they are relevant
Not sure yet..., but eventually to estimate impact of uncertainty on climate simulations
Most likley I will not use the uncretainty information
we use MCMC inversion schemes and will use them as informative priors
To evaluate the accuracy of the analysis
filter data for comparison
theoretically, if the thematic content would be adequate and extent sufficient, it could go into determination of uncertainties of derived information.
To assess the quality of my results when combined with climate data
estimation of uncertainty when comparing to ground assessments/ QA/ time series
We currently use uncertainty only when we assimilate data, i.e. not for land cover.
Interpretation of output, check against "common knowledge"
The uncertainty could support studies on the Ensemble representation for land surface. For instance if the uncertainty is genuinely coming from interannual variability it could a candidate for ensemble treatment.
Inform decision making and perfomance based itigation design
To evaluate the data accuracy and to determine the how the uncertainty in ESA data will impact my own driver analysis
Identify which pixels to rule out in LC change studies
probabilities
To eliminate unsuitable data and generate uncertainty on our final results
Weighting models

Table 18: **Complete list of uses of uncertainty.**

6.4.8 On the interest to be involved in the product assessment tasks

Around 54% of the participants are self-defined as Climate and global land surface modeller. The rest are other type of researchers.

6.4.9 Product assessment for modellers

- *Which model do you use?*

Met Office Unified Model including the JULES land-surface model
regional ESM ROM (regional coupled model developed at AWI), MPI-ESM components and family (JSBACH, eventually ICON)
ORCHIDEE + LMDz
several
IFS, LPJ-GUESS
TSEB, ALEXI, dis/ALEXI, HBV
ECMWF land surface scheme (CHTESSEL enhanced multi-layer scheme coupled with CAMA-Flood inundation model)
GIS
DPM (dust), STEP (vegetation), Sarra-H (crops), Kineros2 (water cycle) etc..
GEOS-Chem atmospheric transport model
NMMB-MONARCH
ISAM land surface model
ORCHIDEE
BLUE (LU emissions); ORCHIDEE; JSBACH
SURFEX-ISBA
ISBA (the CNRM land surface model embedded in SURFEX)
UKESM
I have an intention to develop new one.

Table 19: **Complete list of used models.**

- *Would you be interested to be involved in the user assessment tasks? If yes, for which region and for which deadline?*

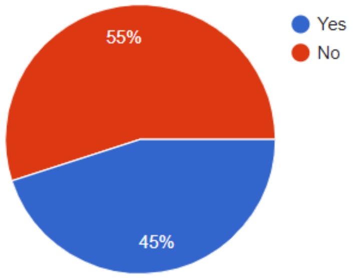


Figure 18: Percent of participants interested in assessment tasks.

For any urban and rural regions affected by climate extremes over recent decades.
high northern latitudes underlined by permafrost, first half of 2020
The regions are not in my area of expertise/interest
"We model the domain of the Barcelona Dust Forecast Center shown here: https://dust.aemet.es/ For that reason, the Sahel domain could be most interesting for us. We follow the schedule of the CMUG project for which a final assessment report is due in Set 2020."
global
tropical Africa
South and South East Asia
Ideally SW US.
Amazon / South America
I say yes, but in fact, the true response depends on the work involved. I have never processed such data myself, it is done by engineers in our group. So the true response does not depend on me, but more on the team head and the engineer working on the LC in our group.

Table 20: **Complete list of regions and deadline for assessment tasks**

- *What would facilitate your involvement in the project?*

A focus on regions affected by climate extremes..
Introduction at least some of the above mentioned features. Furthermore, project that I am working on is funded till October 2020, after that additional resources would be needed.
our work comprises the Sahel region, early data access could be used to evaluate our results
To have as-detailed-as-possible vegetation information [derived from the HRLC data] readily available for us to use.
A workshop defining involvement
Ease of data access.
Socioeconomic and biophysical driver analysis
We are initially working in the SW US. The focus on west Africa could be useful but WPE is known to be happening more in Southern Africa. So any additional focus on SW US, Southern Africa or Australia (with a preference for SW US) would be beneficial for us.
nothing

Table 21: **Answers to facilitation to project involvement**

- *How do you plan to use the HR land cover data?*

for the modelling of land surface variables
For studies on attributing risks of climate extremes (for which accurate vulnerability and exposure data is required).

For evaluation and eventually model development
See two examples given several questions ago
check for regions with high/low LCC dynamics
I intend to combine it with surface energy balance data time series
We could update the land cover information in our model, but need to find additional data for the parts of the domain not covered by the HRLC product. Otherwise we would have to opt for the global MRLC. If more detailed information on vegetation is available (e.g. LAI, cover fraction, …), then we could try to use it.
In global Earth System Modelling aiming at both natural and anthropogenic land surface representation with focus on water energy and carbon cycle to support land-atmosphere fluxes representation (Sensible and Latent heat, Roughness length for momentum, Urban areas identification and radiation treatment, partitioning of CO_2 emissions from natural and anthropogenic surfaces) for improved coupled forecasts and climate reanalyses.
At first to understand carbon fluxes inferred from atmospheric data.
You mean High Resolution. If so, I have already answer of this question above
Not as a modeler. I have a PhD student who will investigate using RS data for studying woody plant encroachment. We can report on how useful these data are for that type of study.
Evaluate LULCC in tropical South America, estimate uncertainties in ELUC due to aggregation.
As boundary conditions in our model
to explore the impacts on climate of land-cover change between 1992 and 2017 and to assess the representation of land-cover in our model
As input data for model of methane emission.

Table 22: **Uses of HR LC data**

6.4.10 Product assessment for other users

- *Which study could you plan to assess with this new HR land cover data product?*

by visiting the field and link it to observation towers.
to implement my local studies
Evaluation of ecosystems services
functional trait calibration using HRLC
To study the changes in land cover data and its relationship with climate change focused in hydrology tasks.
do you mean validate your product, or use your product to validate another product? You could assess your results with https://doi.pangaea.de/10.1594/PANGAEA.884136?format=html#download
Land restoration (geomorphometry) integration in HR land cover
damage assessment/ crown density over time
various. Testing output of a LUC model.
Accuracy Asseement of change data
mangrove mapping and degradation
NPP and water cycle changes
Interaction LC change and CC

Table 23: **Planed studies with HR LC data**

- *Would you perform spatial or classes aggregation?*
- *Would you use any auxiliary products/data in combination with the new HRLC product?*

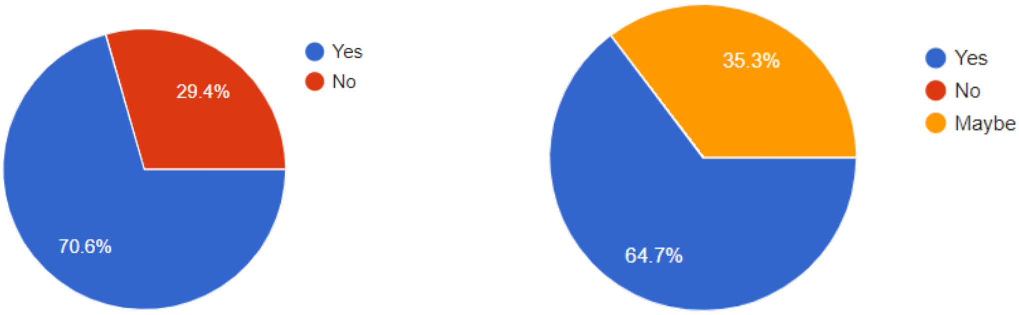


Figure 19: Perform of spatial/classes aggregation (left), and use of auxiliary products (right).

- *Which auxiliary products/data would you use in combination with the new HRLC product?*

drone based data collected
Other satellite imagery and LiDAR data
Surface temperature, LAI, humidity
Vegetation indices
spetroscopy data for traits
Soil textures and LiDAR metrics such as Digital Terrain Models and Tree Canopy Cover.
https://doi.pangaea.de/10.1594/PANGAEA.884136?format=html#download
heighting (with local high resolution DEM, DSM)
Biomass maps
DEM, ground data, SAR...
Altimetry data and satellite images
Time series of pixle values, plus yearly stats
in situ data
Vegetation indices for primary productivity estimation (FPAR, LUE) and thermal data
Own maps

Table 24: **Auxiliary data to be combined with HRLC.**

6.4.11 On the interest to be involved in the product/modelling validation tasks

- *Do you produce in situ data in the study regions?*

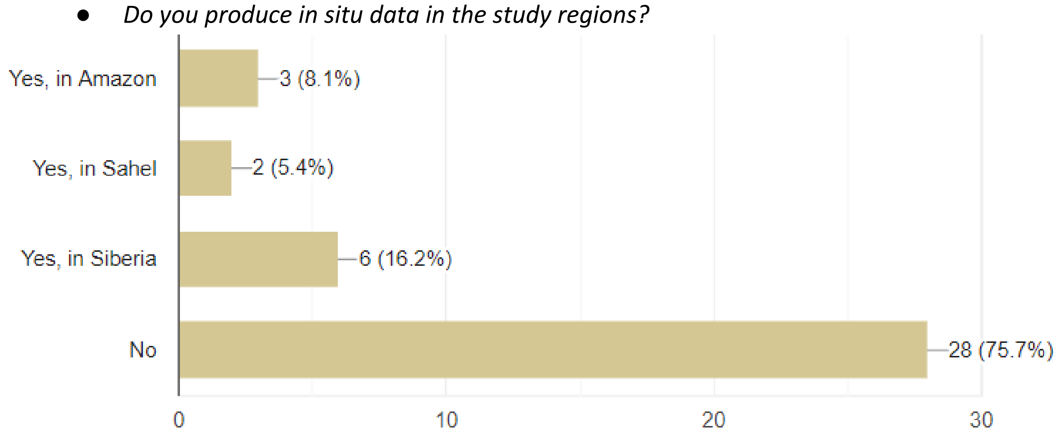


Figure 20: Responses to the data production in the study regions.

If any YES, would you be willing to share these data for the product or model validation within CCI+ HRLC?