LAND COVER CCI

USER REQUIREMENTS DOCUMENT

YEAR 2 – V1.2

DOCUMENT REF:	CCI-LC-URDv2
VERSION:	1.2
CREATION DATE:	2015-07-02
LAST MODIFIED:	2015-12-16

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Document Signature Table

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Document Change Record

VERSION	DATE	DESCRIPTION	APPROVED
0.9	07.07.2015	Draft delivered to UCL	
1.0	13.07.2015	First version delivered to UCL before Annual Review	
1.1	22.10.2015	Second version based on UCL feedback, for ESA review	
1.2	16.12.2015	Updated version to account for M3 RIDs	

From version 1.1 to version 1.2

RID	SECTION	COMMENTS
FR-01	Page 4 / "SYMBOLS AND ACRONYMS" list	The GlobCover Project is in the list of "symbols and acronyms" with the DUE website (http://due.esrin.esa.int/globcover/)
FR-02	Page 12 and 24	Typo FPT was corrected to PFT
FR-03	"Page 21 / Section 2.2.4	A correct description was made about the Image Mode Medium-resolution (IMM - 150 m) and Global Monitoring Image Mode (GM1 - 1,000 m)

From version 1.0 to version 1.1

RID	SECTION	COMMENTS
/	Executive summary	Better reflect the requirements of HR products
/	2.3	Include requirements about HR products (Africa LC map)

Document Diffusion List

ORGANIZATION	NAME	QUANTITY
ESA	O. Arino, F. Ramoino	2

SYMBOLS AND ACRONYMS

AFOLU	: Agriculture, Forestry and Other Land Use
AVHRR	: Advanced Very High Resolution Radiometer
BA	: Burned Areas
CCI	: Climate Change Initiative
CCI–LC	: Climate Change Initiative Land Cover
CMIP	: Coupled Model Intercomparison Project
CMUG	: Climate Modelling User Group
COP	: Conference of the Parties to the UN Framework Convention on Climate Change
COST	: European Cooperation in Science and Technology
ECV's	: Essential Climate Variables
EO	: Earth observation
ESA	: European Space Agency
ESM	: Earth System Modeling/Models
FAO	: Food and Agriculture Organization
FaPAR	: Fraction of Absorbed Photosynthetically Active Radiation
GHG	: Greenhouse gases
GlobCover	: ESA DUE project (http://due.esrin.esa.int/globcover/)
GCOS	: Global Climate Observing System
GM1	: Global Monitoring Image Mode
GOFC-GOLD	: Global Observations of Forest Cover and Land Dynamics
GPG	: Good practice guidance
HYDE	: History Database of the Global Environment
IAM	: Integrated Assessment Modeling
IMM	: Image Mode Medium-resolution
IPCC	: Intergovernmental Panel on Climate Change
ISSI	: International Space Science Institute
LAI	: Leaf area index
LC	: Land Cover
LCCS	: Land Cover Classification System
LSCE	: Laboratoire des Sciences du Climat et de l'Environnement
MERIS	: MEdium Resolution Imaging Spectrometer

MOHC	: Met Office Hadley Center
MPI	: Max Planck Institute
NASA	: National Aeronautics and Space Administration
NDVI	: Normalized difference vegetation index
PFT	: Plant Functional Type
SAR	: Synthetic Aperture Radar
SBSTA	: Subsidiary Body of Science and Technical Advise
SR	: Surface reflectance
TERRABITES	: The Terrestrial Biosphere in the Earth System
UNFCCC	: United Nations Framework Convention on Climate Change
URD	: User Requirements Document
WB	: Water bodies

REFERENCE DOCUMENTS

Applicable documents

ID	TITLE	ISSUE	DATE
[AD-1]	CCI Land Cover project: User Requirements Document	2.2	22.02.2011
[AD-2]	CCI Land Cover project: User Requirements Document v1	1.0	28.07.2014
[AD-3]	CCI Land Cover project: Product User Guide	2.0	02.09.2014

Reference documents

ID	TITLE	ISSUE	DATE
[RD-1]	**IPCC 2006, 2006 IPCC Guidelines for National Greenhouse Gas Inventories**, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Published: IGES, Japan.	Vol. 4	2006
[RD-2]	**Climate Change 2013: The Physical Science Basis**. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. **Chapter 6: Carbon and Other Biogeochemical Cycles**. Ciais, P., C. Sabine, G. Bala, L. Bopp, V. Brovkin, J. Canadell, A. Chhabra, R. DeFries, J. Galloway, M. Heimann, C. Jones, C. Le Quéré, R.B. Myneni, S. Piao and P. Thornton. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.	-	2013
[RD-3]	**Harmonization of land-use scenarios for the period 1500-2100: 600 years of global gridded annual land-use transitions, wood harvest, and resulting secondary lands. Climatic Change.** Hurtt, G.C., Chini, L.P., Frolking, S., Betts, R., Feddema, J.J., Fischer, G., Hibbard, K.A., Janetos, A.C., Jones, C., Klein Goldewijk, K., Kindermann, G., Kinoshita, T., Riahi, K., Shevliakova, E., Smith, S., Stehfest, E., Thomson, A., Thornton, P., van Vuuren, D. & Wang, Y.P. Climatic Change.	Vol.109	2011
[RD-4]	**Holocene carbon emissions as a result of anthropogenic land cover change.** Kaplan, J.O., Krumhardt, K.M., Ellis, E.C., Ruddiman, W.F., Lemmen, C. & Klein Goldewijk, K. The Holocene.	Vol. 20	2010
[RD-5]	**Long term dynamic modeling of global population and built-up area in a spatially explicit way: HYDE 3.1.** Klein Goldewijk, K., Beusen, A. & Janssen, P. The Holocene.	Vol. 20	2010
[RD-6]	**The HYDE 3.1 spatially explicit database of human induced land use change over the past 12,000 years.** Klein Goldewijk, K., Beusen, A., van Drecht, G. & de Vos, M. Global Ecology and Biogeography.	Vol. 20	2011
[RD-7]	**Estimating historical changes in global land cover: Croplands from 1700 to 1992.** Ramankutty, N. & Foley, J.A. Global Biogeochemical Cycles.	Vol. 13	1999

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EXECUTIVE SUMMARY

Within the European Space Agency (ESA), the Climate Change Initiative (CCI) is a global monitoring program which aims to provide long-term satellite-based products to serve the climate modeling and climate user community. Land Cover (LC) has been selected as one of the Essential Climate Variables (ECVs) which were elaborated during Phase 1 of CCI (2010-2013). Now in Phase 2 (2014-2016), CCI is aiming to improve the LC products in terms of products, systems, time frame, and validation. In Phase 1, the CCI–LC project conducted a user requirements analysis to derive the specifications for a new global LC product addressing the needs of key-users from the climate modeling community. Considering these requirements (see Table S-1-1), the CCI–LC team released in 2014 three global LC maps representative for the 2000, 2005, and 2010 epochs (5-year period) together with land surface seasonality products (vegetation greenness, snow occurrence, and burned areas occurrence), a global map of open permanent water bodies, the full archive of Meris surface reflectance images, and a User Tool for data manipulation. All these products are publically available for the climate and LC communities at the ESA-CCI Viewer website: http://maps.elie.ucl.ac.be/CCI/viewer/

As part of the activities of Phase 2 of CCI, two new user surveys were conducted among the climate modelling partners of the CCI–LC project to analyze the fulfillment of the requirements defined in Phase 1 and to identify target requirements for future LC products. This is an iterative process of Phase 2 and considered a first survey during Year 1 of the project and a second survey during Year 2 (this document). In the present User Requirements Document (URD), the comprehensive user survey results of Phase 1 has been reanalyzed excepted future modeling requirements and consolidated through synthesizing new user needs from the scientific community from initiatives such as TERRABITES, ISSI special group, from CMIP 6 process and the outcomes of the 5th assessment report of the IPCC. The Global Climate Observing System (GCOS) process has started to specify new ambitions for ECVs to meet the needs of the climate mitigation community – this also poses new requirements for the CCI–LC project.

The results of the URD Phase 2 – Year 2 (this document) are summarized in Table S-1-1. Although some of the LC products have not been used yet by the users (i.e. MERIS land surface, snow occurrence, and burned areas occurrence), the climate modelers partners of the consortium judged the quality of the tested LC products (LC maps, vegetation greenness, water bodies, and user tool) as moderate to good. The evaluation of the LC products has improved from Year 1 to Year 2 of Phase 2. All threshold requirements of Phase 1 have been met except for the precision in description of land cover thematic characteristics. Here the user recognized that significant progress was done with the definition of cross-walking tables. Accuracy issues detected in Year 1 related to the cross walking tables to convert LC to PFTs have been revised and the new version, including a separation by climatic regions, has been considered by all key users. The users still note some remaining problems in the compatibility with their plant functional type (PFT) parameterization schemes. Phase 1 target requirements have not been met at this stage. All users judged the communication between data users and producers as very good with some minor problems.

Finally, key users were asked to give feedback on the high resolution (10 m) LC map over Africa elaborated during Phase 2. There was agreement on the main LC classes to be included at high resolution (forest, shrub, and grass classes) and, to some extent, on sub-classes (C3, C4 plants and deciduous/evergreen forests). However, requirements need to be further discussed before defining the future LC classes for a high spatial resolution product.

The feedback from Phase 1 and Phase 2 results and the new user's needs assessment have resulted in a series of requirements defined with different levels of priority. These requirements are:

Highest priority

- Longer temporal extent for LC maps including datasets for the 1990's and the 1980's. Consistency between existing (2000-2010) and the new LC maps is essential, as well as, documentation about the limitations on the expanding the time span.
- Higher temporal resolution: annual time steps in LC change, for use in simulating the impacts of historical land use change on the earth system.
- More specific information of land cover/use change is required, at least in the context of the IPCC land categories with changes related to forests, agriculture, grassland defined as highest priority.
- Further improve the description of LC characteristics in the context of PFT model requirements. The remaining problems are related with the definition of climate regional variation (it has been suggested to revise this with climate mapping experts) and some missing PFTs classes (e.g. crops, pastures, rain green shrubs, moss/lichen, C3-C4 grasslands).
- Provide additional relevant and consistent with LC attributes: vegetation height, LAI (min. and max.), C3/C4 plants distinction, and aboveground biomass.
- Provide additional relevant LC seasonality products with vegetation and soil surface albedo being of highest importance.

Lower priority

- Move to 30 m (or better) scale LC and change assessments, at least for selected regions.
- Provide additional relevant LC attributes: clumping index, vegetation density, and land management
- More consistency for the water bodies product (clear separation of inland water vs. ocean, and wetlands) and exploration of adding a water bodies seasonality products to catch irrigated areas and wetland dynamics
- Other desirable LC seasonality products indicated by the key users are: LAI, FAPAR and permafrost fraction, irrigated areas and wetlands, land surface temperature, and soil moisture (for current models); LAI per PFT and forest canopy gaps (for future models).
- Improve the description of the results and products. Besides the detailed technical reports, short technical summaries highlighting important points should be provided.
- Clarification on the Evapotranspiration (ET) product to make it more comparable with model outputs and other ET products currently used by the models

Table S-1-1: Threshold (minimum) and target (optimal) requirements identified for LC products in the User Requirements Survey carried out in the CCI–LC project Phases 1 and 2. ✓ indicates fulfilled requirements.

	Threshold requirement Phase 1	Target requirement Phase 1	Threshold requirement Phase 2	Target requirement Phase 2
Coverage and sampling				
Geographic coverage	Global ✓	Global with regional and local specific products ✗	Global with regional specific products	Global with regional specific products
Temporal sampling	Best/stable map and regular updates ✓	Monthly data on vegetation dynamics and change ✗	5-10 year epoch maps with monthly vegetation dynamics (NDVI)	1-year epoch maps. Monthly data on vegetation dynamics (NDVI)
Temporal extent	1-2 years, most recent ✓	1990 (or earlier)-present ✗	1990 (or earlier) - present	1980 (or earlier) - present
Resolution				
Horizontal resolution	1000 m ✓	30 m ✗	300 m with regional 30 m products	30 m
Vertical resolution	–	–		
Error/Uncertainty				
Precision	Thematic LC detail sufficient to meet current modelling user needs ✗	Thematic LC detail sufficient to meet future model needs ✗	Thematic LC detail (incl. conversion tables to PFT for climatic regions) sufficient to meet current and future model needs, incl. key land IPCC changes	Thematic LC detail (incl. conversion tables to PFT for climatic regions and traits) sufficient to meet current and future model needs, incl. LC changes and management
Accuracy	Higher accuracy than existing datasets ✓	Errors less than 5-10% either per class or as overall accuracy ✗	Higher accuracy than existing datasets	Errors less than 5-10% either per class or as overall accuracy
Stability	Higher stability than existing datasets ✓	Errors less than 5-10% either per class or as overall accuracy ✗	Higher stability than existing datasets	Errors less than 5-10% either per class or as overall accuracy
Error characteristics	Independent onetime accuracy assessment ✓	Operational and independent multi-date validation ✗	Independent multi-date validation	Operational and independent multi-date validation

1 INTRODUCTION

1.1 Background

The objective for the Phase 1 of the project (2010-2013) was to critically revisit all algorithms required for the generation of a global land product in the light of the GCOS requirements, and to design and demonstrate a prototype system delivering in a consistent way over years and from various Earth Observation (EO) instruments global land cover information matching the needs of key users belonging to the climate change community.

In Phase 2 (2014-2016), the CCI–LC project aims to improve the achievements of Phase 1 in terms of products, systems and validation; expand the temporal extent of the products to 1980's and 2013-2016 periods using AVHRR, Sentinel-3 and Proba-V datasets; demonstrate the feasibility of building up high resolution global LC products (10-20 m) over Africa by using Sentinel-2 data supplemented by Landsat 8 data; and extend the climate impact assessment of a better land surface description for climate modelling.

The policy background for monitoring ECVs is the UNFCCC requiring global land cover observation progress relates to research and systematic observations. The scope is to continuously monitor ECVs to reduce uncertainties in understanding the global climate system, which includes LC as one such variable. The related GCOS implementation plan (GCOS tasks defined in 2004 have been redefined in 2010) specifies a number of specific tasks to improve the global observation of land cover as an essential climate variable including (1) the establishment of international standards, (2) consensus methods for map accuracy assessment, (3) the continuity for fine-scale satellite observations, (4) the development of an in situ reference network and the implementation of an operational validation framework, (5) the generation of annual global LC products, and (6) the development of a high-resolution global land cover change dataset. As requested by the UNFCCC Subsidiary Body of Science and Technical Advise (SBSTA), reporting guidelines and standards are being developed for each ECV including land cover. Progress on this issue is documented at http://www.fao.org/gtos/topcECV.html.

Any ECV monitoring effort has to ensure saliency and legitimacy in addition to technical credibility. An international coordination mechanism among key actors worldwide (users, producers, science, regional/national experts) is essential to ensure that land cover products are accepted internationally and by the UNFCCC. Such mechanisms are intrinsic to the CCI–LC project and will be described in more details in chapter 3.

In the Phase 1 of the project, detailed user specifications have been derived for a global land cover product, matching the requirements from GCOS (both for itself and as a surrogate for other important climate variables) and key climate users, which could be achievable on a regular basis using the current EO systems and building on the UN Land Cover Classification System (UN–LCCS) for consistency and interoperability with other land cover products.

The tasks carried out for WP1101 were:

1. Provide a review of climate modeling user feedback from the Phase 1 and capture evolving requirements from the scientific community

2. Assessing evolving GCOS requirements, in particular for linking ECV's more to the needs of climate change mitigation
3. Document and synthesize the requirements and provide contributions and lead of discussions for a user interaction and product specification activities within the project.

1.2 Scope

This document describes the activities and results of the user requirements analysis. It will serve as a basis for the products specification of the Land Cover project within ESA's Climate Change Initiative Program, CCI–LC Phase 2. The user requirements assessment of Phase 2 of the project is an iterative process (as defined in WP 1101/1102) and considered a first survey during Phase 2 - Year 1 of the project and a second survey during Phase 2 - Year 2 (this document).

1.3 Structure of the document

This technical report is not repeating the URD of Phase 1 which still contains a lot of useful information for land cover related user requirements. After this introduction, an overview of the evolving user requirements is presented:

- Section 2 gives the main results of the user requirement analysis made in Phases 1 and 2. It includes the users' requirements considered in Phase 1 (section 2.1), a description of the products released in 2014 (section 2.2), the corresponding feedbacks from the climate users after testing these products (section 2.3) in the surveys carried out in Phase 2 – Year 1 (reported in URD v1) and Phase 2 – Year 2 (this document);
- Section 3 presents the updates from the GCOS process;
- Section 4 explains the evolving users' requirements. Section 4.1 discusses the key users' expectations for Phase 2 while sections 4.2 and 4.3 detail the requirements from climate-related land use - land management community and from long-term LC reconstructions, respectively;
- Section 5 recapitulates the users' requirements of Phase 2 – Year 2.
- Section 6 includes two appendices. Section 6.1 details the survey form sent to the climate modelers of the consortium during Phase 2 – Year 2 and section 6.2 presents a synthesis of the associated results.

2 RESULTS OF PHASES 1 AND 2

2.1 Users' requirements from Phase 1

The process of climate user interaction has been started and defined in Phase 1 of the project. Several actors and types of users were involved in representing the modeling communities concerned with climate and climate change issues. The structure to ensure a continuous dialogue with the climate community in different execution stages included three main phases: broad review of user requirements, participation in the Climate Modelling User Group (CMUG) process, and engagement in scientific dialogs for harmonization efforts of land cover data.

Identification of specific user needs for product specifications:

1. Broad review of user requirements from the scientific literature including existing uses of land cover data for climate modeling but also of innovative concepts and approaches to better reflect land dynamics in the next generation of models. This includes a detailed survey of the project key and associated users, their requirements and related synthesis to derive product specifications;
2. Participation in the CMUG process and attendance to key meetings and conferences;
3. Active engagement in scientific dialogs among climate change modeling community, i.e. on harmonization efforts for land cover among the Earth System Modeling (ESM) and Integrated Assessment Modeling (IAM) communities.

User application and feedback mechanism from the users on the use of the products and related potentials and limitations:

1. Key users were asked to use the products generated in their applications to provide first indications on the potentials and limitations;
2. Final discussions with the users yielded feedback on the products and resulted in a set of recommendations to further improve ECV land cover monitoring beyond this project.

In CCI–LC Phase 1, three user surveys were completed for the broad, associated and key users respectively. The surveys highlighted that land cover has been and remains a fundamental dataset as consistent input to climate models and for the integration of other data sources. While it is assumed that any new land cover datasets should be better than previous ones and improve climate model and assessment performance, there are several ways land cover feed into different climate applications. It has been emphasized that there is a need for both stable land cover data and a dynamic component (time-series and changes). For the purpose of the phase 1 users' survey, three main use of land cover observations and data were considered:

1. As proxies for a suite of land surface parameters that are assigned based on PFTs;
2. As proxies for human activities in terms of natural versus anthropogenic and tracking human activities, i.e. land use affecting land cover (land cover change as driver of climate change);
3. As datasets for validation of model outcomes (i.e. time series) or to study feedback effects (land cover change as a consequence of climate change).

The surveys not only asked for current but also for future and expected modeling requirements. Thus, it is important to first assess again the outcomes of the Phase 1 survey for the purpose of Phase 2.

2.1.1 Accuracy

There are three types of quantitative requirements provided for the accuracy of the CCI–LC products coming from GCOS, the CMUG and the CCI. Given the fact that available land cover maps have an overall area weighted accuracy of around 70%, it can be assumed that the accuracy requirements for the land cover CCI should be higher. Secondly, GCOS requirements mention a maximum of 15 % omission/commission errors per class while those from the CMUG and the CCI require an error of 5-10 %. CMUG further requires stability in accuracies over time of more than 10%. Those requirements can be understood as quantitative guideline, however, from current knowledge in global land cover mapping experiences there are two main problems in using such statements for the upcoming land cover mapping efforts:

1. Errors less than 5-10 % either per class or as overall accuracy are rare and hard to achieve in any land cover mapping effort with more than a 2-3 categories,
2. The accuracy of the products depends on its actual use in the model.

The users also stressed the need for quality flags and controls, the probability for the land cover class or anticipated second class or even probability distribution function for each class (coming from the classification algorithm), and the need for accuracy numbers for land cover classes (potentially also with regional estimates).

2.1.2 Spatial detail

There is not one spatial resolution that fits all purposes; it is important that the land cover product provides flexibility to serve different scales and purposes. On average, climate models run on broad spatial levels of detail and a resolution of 300 m or coarser is sufficient to meet modeling requirements for most users. However, for some and in particular for future periods there are requirements of more detailed resolutions. This would mean that land cover observations to estimate model parameters and for description of change would need towards fine-scale satellite observations coming from Landsat-type observations in the coming years (e.g., Sentinel-2).

2.1.3 Temporal resolution

Many users use annual updating of parameters initially derived from land cover data. While annual data are currently not available for land cover, the modeling community is using interpolation and ancillary data (i.e. from the literature or models) to provide the temporal details required. The need for increased temporal resolution data is pertinent among all user groups, in particular for future periods moving into considering intra-annual and monthly dynamics of land cover. While any addition to the temporal resolution of the currently often static land cover data is useful, the need to explore the potential of dense remote sensing time series signals is of fundamental importance. In terms of the temporal range, models use periods beyond the remote sensing era back in time and this range is expected to further increase in the future.

2.1.4 Land cover categorization

While almost all major land categories in current maps are of importance, the surveys particularly highlighted the need for 3 major classes in current models: forest, herbaceous, and agriculture classes.

Considering all users, the need for wetland and urban classes is expected to increase in future model and other land cover applications. Forests and some of other vegetation classes (i.e. shrubs) are commonly separated by leaf type and phenology. Given the fact that users require a suite of different types of land cover categories (or PFTs) for model parameterization that varies with the type of model and the modeling approach, any land cover product will need to provide some flexibility in responding to these different thematic needs.

Users also highlighted the need for additional information on the separation of C3/C4 grasses and crops and the consideration of human activities and land management practices. For example, the "disturbed fraction" of LC has been advocated as one of such requirements.

2.1.5 Land surface dynamics and land cover change

The need for land cover change and dynamic products from remote sensing is highlighted as increasingly important in current modeling and also pertinent in the future.

The most important information is required for:

1. Vegetation phenology
2. Agricultural expansion
3. Forest loss/deforestation
4. Urbanization

In addition, the needs for monitoring wetland dynamics, fire, land degradation and long-term vegetation trends are highlighted by the community of associated users. It is also important to note that about half of the broad user community and four fifth of the associated users mentioned the need for any change/dynamic information. This re-emphasizes the need for both stable and dynamic components describing the land cover.

2.1.6 Metadata, quality control, format, projection and data access

Metadata, including various items, are required with satellite climate data records. Next to standard metadata items, some specific requirements on quality control were mentioned by the user assessment:

1. Validation information: specific areas which were checked with in situ data, and level of agreement with other land cover datasets;
2. Clear description of classification methodology and underlying assumptions (e.g., cloud and snow mask);
3. Information to support assessment of consistency with other EO derived products (e.g., albedo, vegetation-activity).

NetCDF was requested as the preferred format. The use of a geographic lat/lon coordinates is proposed as spatial reference system.

Data access through FTP (also combined with web services) is the preferred option for the climate user community.

2.2 Release of the CCI–LC products

The users' requirements analysis [AD-1] highlighted the expectations of the climate communities for an improved land cover product which would include both stable and dynamic components. A revisited LC concept was therefore introduced, which distinguished the LC state and LC condition components. The LC state concept refers to the set of LC features remaining stable over time which define the LC independently of any sources of temporary or natural variability. It was agreed that the LC state is well described using the UN–LCCS, which is also quite compatible with the Plant Functional Types (PFT) concept of many models. The LC condition concept directly relates to the temporary or natural variability of LC features that can induce some variation in land surface over time without changing the LC in its essence. It is typically driven by biogeophysical processes. It encompasses different observable variables such as the green vegetation phenology, snow coverage, open water presence, burned areas occurrence, etc.

The CCI–LC team has developed and released five key products to its climate modelers in August 2013, and to the general climate and LC communities, in October 2014 [AD-3]. Currently, these products can be freely visualized and accessed online at http://maps.elie.ucl.ac.be/CCI/viewer/

The CCI-LC products are:

1. Three global LC maps representative for the 1998-2002, 2003-2007 and 2008-2012 epochs,
2. The full archive (2003-2012) of MERIS full resolution time series pre-processed in 7-day composites,
3. Three land surface seasonality products describing the vegetation greenness, the snow and the burned areas occurrence dynamics,
4. A global map of open and permanent water bodies at 300m spatial resolution,
5. A user tool for sub-setting, re-projecting and re-sampling the products.

2.2.1 Global LC maps for the 2000, 2005 and 2010 epochs

The 3 global LC maps were produced using a multi-year and multi-sensor strategy in order to make use of all suitable data and maximize product accuracy. The entire 2003-2012 MERIS Full and Reduced Resolution (FR and RR) archive was used as input by UCL-Geomatics to generate a 10-year 2003-2012 global land cover map [AD-3]. This 10-year product has then served as baseline to derive the 2010, 2005 and 2000 maps using back-dating techniques with MERIS and SPOT-Vegetation time series specific to each epoch. In order to meet the user requirements defined in Phase 1, the map proposes a legend based on the United Nations – Land Cover Classification System (UN–LCCS) with the view to be as much as possible compatible with the GLC2000, GlobCover 2005 and 2009 products. The level of thematic details was found to be improved with respect to previous global LC products. Each map is characterized by a set of quality flags. The map was delivered with a tool for sub-setting, re-projecting and re-sampling the products in a way which is suitable to each climate model. This tool also allows converting the LCCS legend to user specific PFTs.

2.2.2 MERIS surface reflectances

The surface reflectance (SR) products consist of MERIS global time series covering the 2003-2012 period. The spectral content encompasses the 13 surface reflectance channels - the atmospheric bands 11 and 15 being removed - and the spatial resolution is of 300 m for FR and 1000 m from the RR. The time series are made of temporal syntheses obtained over a 7-day compositing period. In order to simplify the handling and analysis of global datasets, the MERIS SR time series are delivered in 5°x5° tiles [AD-3].

2.2.3 Land surface seasonality products: vegetation greenness, snow occurrence and burned areas occurrence

As already mentioned, the land surface seasonality products describe the dynamic aspect of the LC. In in October 2014, the CCI–LC project officially released 3 global seasonality products: vegetation greenness as shown by the Normalized Vegetation Index (NDVI), snow occurrence, and burned areas (BA) occurrence. On a per pixel basis, these LC condition products reflect, along the year, the average trajectory (or behavior) and the intra-annual variability of a land surface feature over the 1999-2012 period (NDVI) and 2000-2012 (snow and BA). They are expressed as aggregated 7-day time profiles of the mean and standard deviation for continuous variables (NDVI) or as temporal series of occurrence probabilities for discrete variables (snow, BA and water). These products are complementary to the three CCI global maps products characterizing the same period. They were built from existing global long-term datasets which beneficiate from high temporal frequency and moderate spatial resolution.

The vegetation greenness product was built from the SPOT-Vegetation (1km spatial resolution) time series over the 1999-2012 period. The BA product covers the 2000-2012 period with data originating from the MODIS Direct Broadcast Monthly Burned Area Product (MCD64A1 - 500m spatial resolution) being part of the Global Fire Emissions Database version 3 (GFED.v3) products. The snow product was built from the MODIS/Terra Snow Cover 8d L3 Global 500m SIN Grid product (MOD10A2 - 500m spatial resolution). Each seasonality product is delivered in 52 files (1 file per 7-day time interval) and each file made of measurements and quality flag layers.

2.2.4 Water bodies product

In an attempt to improve characterization of inland water bodies (WB) and oceans in global LC products, a SAR-based approach has been implemented. The land/water classification is derived from multi-temporal metrics based on time series of the backscattered intensity recorded by the ASAR instrument onboard the ENVISAT satellite between 2005 and 2010 (occasionally up to 2012 to avoid data voids). The main source of ASAR imagery is the Wide Swath Mode (WSM) at 150 m spatial resolution. As the quantity of WSM was insufficient in some places, imagery Image Mode Medium-resolution (IMM - 150 m) and Global Monitoring Image Mode (GM1 - 1,000 m) were used in complement [AD-3]. The CCI-LC SAR WB product was finally obtained after consolidation of the refined product to remote local artefacts, fill classification voids and aggregate to 300 m.

2.3 Feedback from key users (surveys Phase 2 – Year 1 & Phase 2 – Year 2)

2.3.1 Methodology

In order to assess whether the user requirements of Phase 1 were fulfilled by the LC products released internally in 2013 and to identify new requirements for future LC products, two detailed user survey have been conducted among the climate modelling partners of the ESA–CCI program and Land Cover CCI project, specifically:

1. Met Office Hadley Center (MOHC, UK)
2. Max Planck Institute for Meteorology (MPI, Germany)
3. Laboratoire des Sciences du Climat et de l'Environnement (LSCE, France)

In these surveys, specific requirements for land cover data characteristics used (e.g., spatial, temporal, thematic detail, accuracy requirements) for current and future climate modelling applications have been assessed. The detailed survey for these three key-users (section 6.1) was conducted through email. The results of the survey carried out in the Year 1 of Phase 2 were discussed in the User Requirement Document v1 [AD-2] and the results of the Phase 2 – Year 2 survey are presented and consolidated with the previous one in the User Requirement Document v2 (this document). A synthesis of the results of this last survey is provided in Appendix 2.

As mentioned before, the URD is an iterative process and Year 2 Survey was designed according to the feedback obtained from Year 1 Survey. The differences in section numbering, contents, and structure between the two Key User Surveys are explained in Table 2-1: Contents, structure, and differences between the Key User Surveys carried out in Phase 2 – Year 1 and Phase 2 – Year 2.Table 2-1.

Table 2-1: Contents, structure, and differences between the Key User Surveys carried out in Phase 2 – Year 1 and Phase 2 – Year 2.

	Phase 2 – Year 1		Phase 2 – Year 2		Differences from Year 1
	Section name	Nb of questions	Section name	Nb of questions	
1	General information	4	General information	3	Questions 3 and 4 were merged into 1 according to the new names of the 5 LC products
2	LC products (maps)	12	LC maps	11	Since Year 1 Survey captured the opinion about the LC maps, emphasis of Year 2 was put on: i) ways to improve the products, ii) priority for including new LC classes and attributes, iii) expectation for the upcoming 1990's and 1980's maps and high resolution LC map, and iv) LC change. Some questions about LC features were integrated into 1.
3	LC condition products	4	Land Surface Seasonality products	9	At the time Year 1 Survey was carried out none of the Key Users had been tested the LC condition products. Thus, special emphasis was put on these products in Year 2 Survey. Additional questions were added about i) experience using the evapotranspiration product and ii) priority for including new LC condition products.

4	Communication between LC users and producers	5	Meris Surface Reflectance	7	Considering the improvements on products and systems development the LC products Meris Surface Reflectance, Water Bodies, and User Tool were surveyed under different sections and in more detail than the previous survey.
5	Final remarks	1	Water Bodies	5	
6	-	-	User Tool	5	
7	-	-	Communication between LC users and producers	5	This section is the same as Year 1
8			Final remarks	1	This section is the same as Year 1

2.3.2 Main results

The main results of the key user survey (Phase 2 – Year 2) are provided as follows:

2.3.2.1 General aspects

The survey was completed by the three key users (MOHC, MPI and LSCE) as shown in Figure 2-1. All these climate modelling groups used the LC products (three epochs). Regarding Land Surface Seasonality products, only vegetation greenness was used by two users while snow occurrence and burned areas (BA) occurrence were not used. Finally, the Water Bodies product was used by two users, the Meris Surface Reflectance product by none, and the User Tool by all three key users.

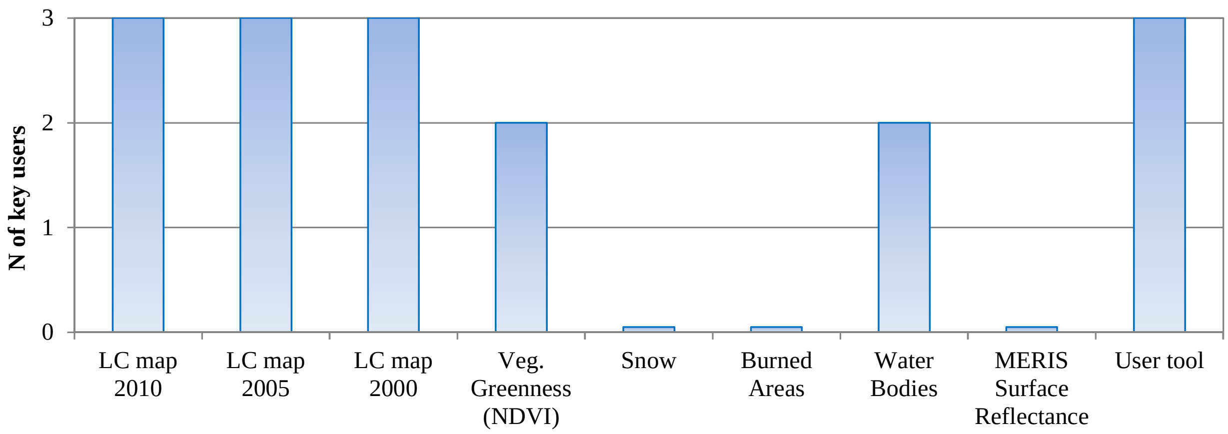

Figure 2-1: LC products tested by the key climate modelling users in Phase 2- Year 2

2.3.2.2 Land Cover maps

The following aspects of the LC products were considered by the key users as completely satisfactory for their climate modelling applications in both Year 1 and Year 2 surveys:

1. Spatial detail (300x300m)
2. Projection (lat/long)
3. Format (NetCDF, GeoTIFF)

Other aspects such as accuracy, consistency, LC categories, temporal extent, and temporal resolution were not evaluated as optimal in all cases by the key users (Figure 2-2), although in many cases improvements have been achieved from Year 1 to Year 2 of Phase 2.

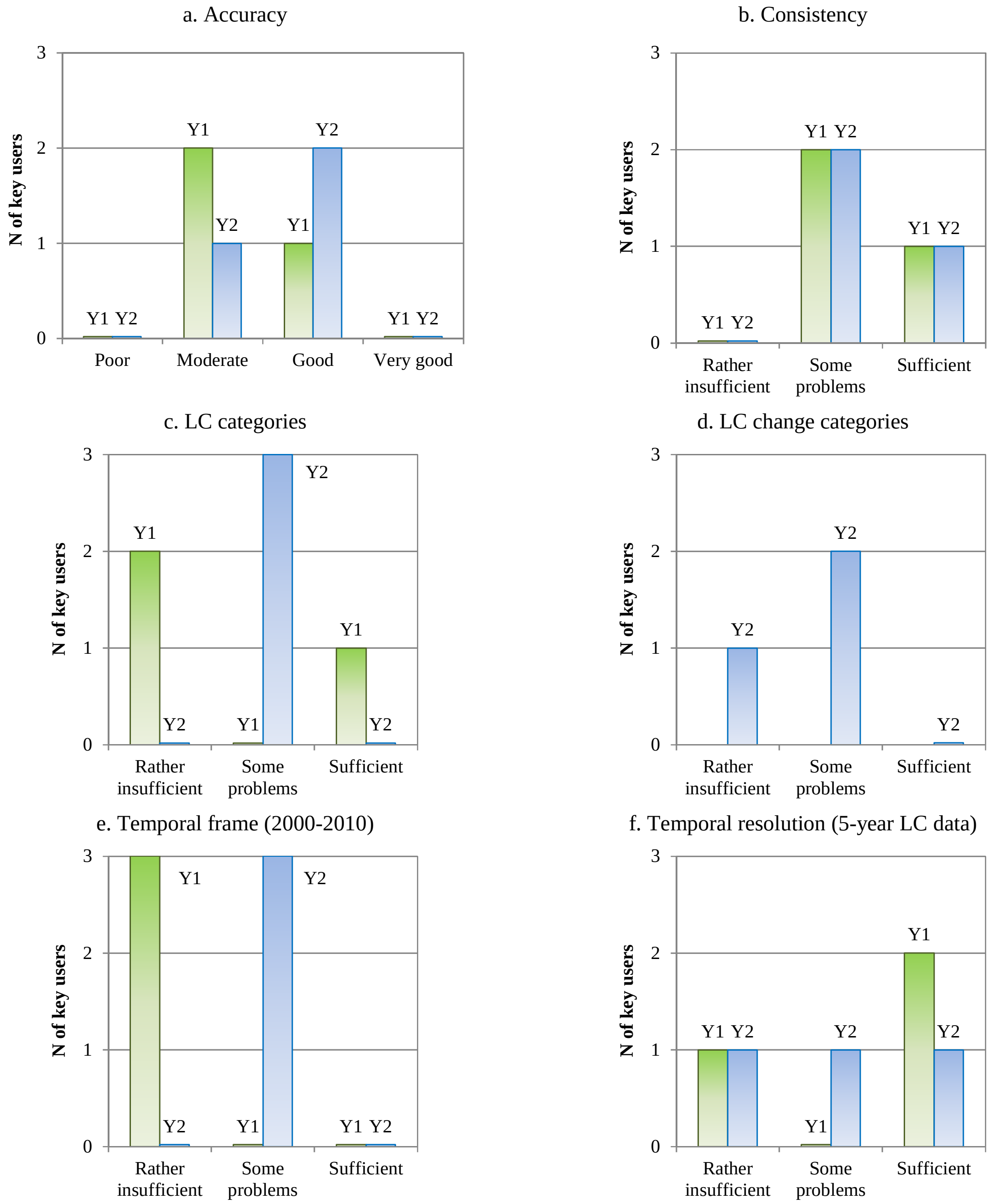

Figure 2-2: Aspects of the LC products that need improvement according to the Phase 2 - Year 1 and Phase 2 - Year 2 Key User Surveys.

Accuracy issues detected in Year 1 related to the cross walking tables to convert LC to PFTs have been revised and the new version, including a separation by climatic regions, has been considered by all key users as 'with some problems'. These problems are related with the definition of climate regional variation (it has been suggested to revise this with climate mapping experts) and some missing PFTs classes (e.g. crops, pastures, rain green shrubs, moss/lichen, C3-C4 grasslands). Key users consider the temporal frame of 2000-

2010 and the temporal resolution of 5-years as a good start, but still the 1990's and 1980's maps are missing. Furthermore, annual temporal resolution is requested. Expectations for the 1990's and 1980's maps were also to have annual temporal resolution, consistency between existing and new LC maps, and to get clear documentation about the limitations on the mapping production. Regarding LC changes, transients between more categories were requested and it was indicated that not all possible LC changes were implemented. Finally, it was suggested to provide more information about how to use the quality flags and suggested to improve metadata information.

In the specifications for the next version of the maps, LC change between epochs should focus on the main IPCC land categories. Key users were asked to define priorities between main IPCC land categories classes. While higher priority was given to the Forest, Agriculture, and Grassland classes, lower priority was given to the Settlement, Wetlands, and Other Land classes (Figure 2-3).

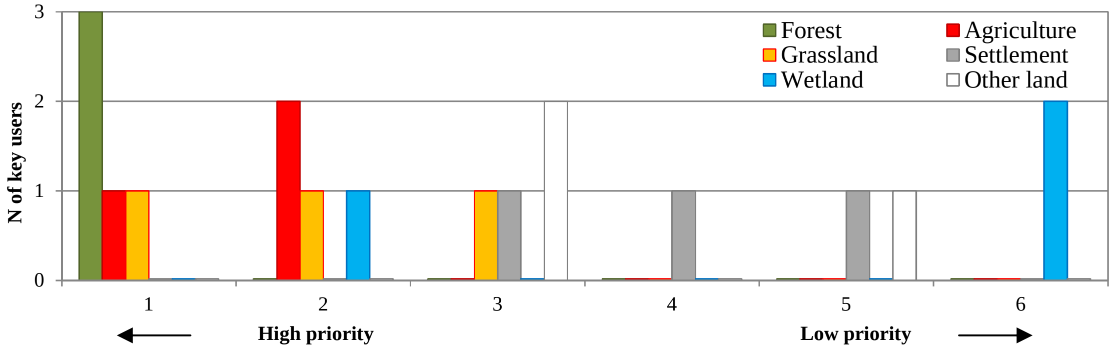

Figure 2-3: Priorities of IPCC land categories that should be identified as LC change between the different LC maps' epochs.

In a similar way, key users were asked to define priorities to include new LC attributes for future modelling applications, but in this case, there was no clear agreement among the different groups (Figure 2-4). Overall, higher priority was given to vegetation height, LAI (min. and max.), C3/C4 plants distinction, and aboveground biomass while clumping index, vegetation density, and land management were considered with lower priority.

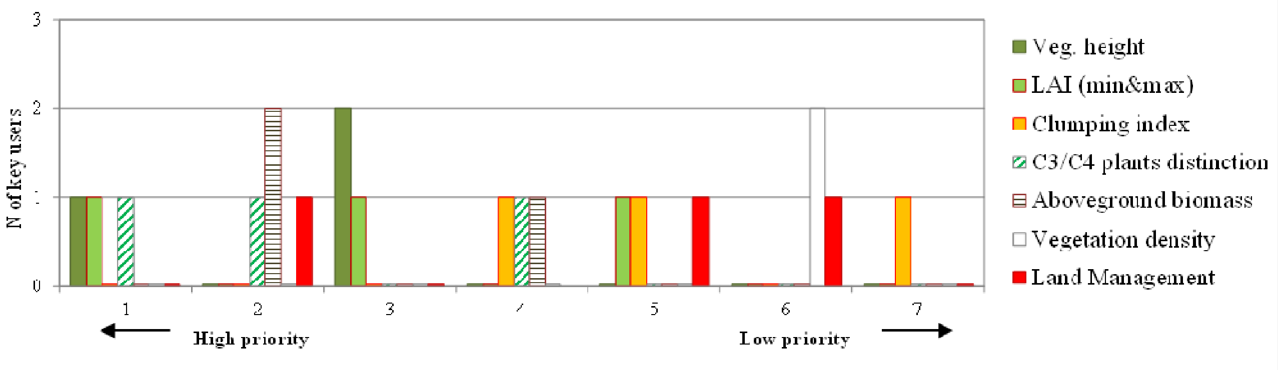

Figure 2-4: Priorities of LC attributes to be included for future modelling applications

Finally, key users were questioned about the high resolution (10-20 m) LC map over Africa that will be elaborated during Phase 2 of the project. They were asked to define their ideal hierarchical legend, i.e. their top 5 level 1 (main classes) and top 10 level 2 (sub-classes) of interest. The first conclusion is that key users did not have yet a clear opinion on the concept of a hierarchical legend. They also have different opinions towards the LC classes and subclasses this high spatial resolution map should have (see Table 2-2). Two key users (MOHC, LSCE) replied while one (MPI) claimed the question was not clear enough (major and minor classes need to be convertible in PFTs anyway). Table 2-2 shows the different requirements defined by two key users. Although there was agreement on some of the Level 1 classes (forest, shrub, and grass classes were present) and, to some extent, on Level 2 (C3, C4 plants and deciduous/evergreen forests), this exercise clearly shows that requirements need to be discussed in detail before defining the future LC classes for a high spatial resolution product.

Table 2-2: LC classes required for a high resolution LC map

Met Office Hadley Centre (MOHC)		Laboratoire des Sciences du Clmat et de'l Environnement (LSCE)	
Level 1 (main classes)	Level 2 (max. 10 sub-classes)	Level 1 (main classes)	Level 2 (max. 10 sub-classes)
L1 Tree cover	L1.1 Broadleaf evergreen (closed) L1.2 Broadleaf deciduous (closed) L1.3 Broadleaf evergreen (open) L1.4 Broadleaf deciduous (open)	L1 Agriculture	L1.1 C3 L1.2 C4
L2 Shrub cover	L2.1 Broadleaf evergreen (closed) L2.2 Broadleaf deciduous (closed) L2.3 Broadleaf evergreen (open) L2.4 Broadleaf deciduous (open)	L2. Grass	L1.1 C3 L1.2 C4
L3 Grass cover	L3.1 Natural C3 L3.2 Natural C4 L3.3 Managed C3 L3.4 Managed C4 L3.5 Cropland C3 L3.6 Cropland C4	L3 Open canopies	L3.1 Mixed of vegetation types for woody savannas (mosaic classes)
L4 Non vegetated	L4.1 Urban L4.2 Bare soil L4.3 Water L4.4 Snow	L4 Evergreen closed forest	
		L5 Deciduous closed forest	Different levels of deciduousness

Regarding LC change trajectories at high resolution, key users defined their priorities as follows:

MOHC: all LC changes between Level 1 classes are top priority

LSCE: only forest to non-forest was requested

MPI: LC changes between forest, crops, grassland, and bare soil

2.3.2.3 Land surface seasonality products

The climate modelling partners did not use/test the snow occurrence and burned areas occurrence products during the Phase 2 - Year 1 of the project. Therefore, this section shows mainly the evaluation and requirements for the vegetation greenness product (NDVI). Vegetation greenness was used as a proxy for land use parameters and validation of model outputs. The only problem reported (only by one user) was the short time frame (1999-2012). None of the key users tested the quality flags or checked consistency between this product and other LC products.

An additional seasonality product, the evapotranspiration (ET) product was tested by two of the climate modelling groups. From a preliminary analysis, ET simulated by the climate models over-estimated ET in comparison with the CCI-LC ET product, although there were differences among climate regions (e.g. overestimation in extra-tropics and underestimation in the tropics for the JSBACH model). Nevertheless, the ET product will need further testing.

Key users were also asked about additional seasonal or LC condition products. Priorities for including new products for modelling applications were i) vegetation and soil surface albedo, ii) FaPAR, and iii) permafrost fraction. Other desirable products indicated by the key users are:

- ***For current models***: LAI, irrigated areas and wetlands, land surface temperature, and soil moisture
- ***For future models***: LAI per PFT, forest canopy gaps.

2.3.2.4 MERIS surface reflectance product

The climate modelling partners did not test this product during Phase 2 – Year 1, although two modelling groups plan to use it in the future.

2.3.2.5 Water bodies product

Two climate modelling partners tested the Water Bodies product during Phase 2 – Year 1. This product was used as a proxy for land surface parameters, validation of model outputs, and additionally, to make comparison between this and other global LC maps. Problems reported for this product were: i) water bodies corresponded to the maximum water extent over the year/timeframe, and it would have been better to have the seasonal or monthly climatology of the water surface, ii) no distinction between inland and marine water bodies was troublesome, iii) some artificial water bodies along the coastlines were reported, and iv) no distinction between wetlands and water bodies made it hard to compare with other datasets. Finally, consistency between the Water Bodies product and other LC products was not checked by the key users at this stage.

2.3.2.6 User tool

All key users used the CCI-LC User Tool and found it useful. Similarly, all users used the LC class – PFTs convertion tool and tested the default cross-walking table, while two groups additionally used a user-defined cross walking table. In general, the key users evaluated as ‘sufficient’ all the functionalities of the User Tool. Key aspects for future improvement of the User Tool are the distinction between C3-C4 plants, the biomes delineation, convertion to more classes (crops, pastures, raingreen shrubs), and the possibility of using different cross walking tables per biome. Details are presented in the Appendix 6.2.

2.3.2.7 Communication between ESA–CCI–LC producers and users

Communication between producers and users (including reporting) was found as ‘with some problems’ and reports as ‘useful’ by the three key users. The problems indicated were: i) some specific delays on data transference, ii) out-of-date mailing list distributions, iii) miscommunication on the land cover change issue. Suggested ways to improve communication with climate modelling users are: i) inform by mail when new products or product version are released (up-to-date mailing list), ii) to have 2-slides summaries of ‘highlights for climate users’ at the end of the project meetings, and iii) prepare a ‘key message for users’ document as a primary technical report document.

2.3.2.8 Conclusions

1. Longer temporal extent for LC maps (30 years and more) is required to address the issue of LC change. Although the upcoming 1990’s and 1980’s LC maps for the 1990’s will fulfill this requirement, key users stressed out that consistency between the existing 2000’s LC maps and the new maps is a key issue for modelling applications;
2. Higher temporal resolution is required: annual time steps in LC change. This is also requested for the 1990’s and 1980’s LC maps;
3. Implement more LC changes (all possible combinations);
4. Some of the PFTs required by current climate models could not be derived from the LC classes (e.g. crops, pastures, rain green shrubs, moss/lichen, C3-C4 grasslands). More specific classes are required;
5. Higher priorities to include new LC attributes for modelling applications were given to vegetation height, LAI (min. and max.), C3/C4 plants distinction, and aboveground biomass.
6. Higher priorities of IPCC land categories that should be identified as LC change between the different LC maps’ epochs were Forest, Agriculture, and Grassland classes.
7. The priority for including new LC condition products for modelling applications was defined by the key users by i) vegetation and soil surface albedo, ii) FaPAR, and iii) permafrost fraction;
8. Other desirable LC condition products indicated by the key users are: LAI, irrigated areas and wetlands, land surface temperature, and soil moisture (for current models); LAI per PFT and forest canopy gaps (for future models);
9. Access to the whole time series of LC condition products is requested;
10. Better explanation of the use of quality flags is requested.

3 UPDATES FROM THE ECV STRATEGIC LEVEL: THE GCOS PROCESS

While GCOS is in the process of updating its implementation plan for UNFCCC COP 2015 in Paris, it has taken action to also consider the role of ECV monitoring for the purpose of climate change mitigation and adaptation. Mitigation and adaptation are the two central approaches in the international climate change process. Mitigation involves human interventions to reduce greenhouse gas emissions, and to enhance their removal from the atmosphere, including by forests, vegetation or soils that can absorb carbon. According to IPCC, there is significant mitigation potential on a global scale, including the increased use of clean technologies and improved energy efficiency, reducing deforestation and improving land use practices.

Long-term observation is fundamental to the provision of sound and accessible environmental information and to sustainable environmental resource management globally. Opportunities to improve the quality of observations need to be pursued in order to strengthen information available on a global basis; in particular for the least developed regions. GCOS and GOFC-GOLD aim to ensure that all users have access to the observations, data records and information that they require to address pressing climate-related concerns, particularly in support of mitigation and adaptation. So far the monitoring of Essential Climate Variables (ECVs) identified by GCOS has largely been focused on the observing the physical climate system, the needs of climate modelers and IPCC WG 1-type users with little attention paid to human activities and the needs and requirements of mitigation.

Accordingly, GCOS and GOFC-GOLD organized an expert meeting, which took place from 5 to 7 May 2014, in order to identify observational requirements for mitigation, to review the Essential Climate Variables (ECVs) and associated guidelines to consider their adequacy for mitigation, and to develop a plan to address any gaps and deficiencies identified. The meeting focused on land use (forests and agriculture) to exemplify ideas and options to expand upon ECV observations because this is the currently the sector with currently the largest data gaps and user needs, and also the sector where the ECV concept seems most relevant to mitigation. More specifically:

1. The workshop clarified what is meant by land-based mitigation based on priorities and activities discussed and presented in the recent IPCC AR5 WG III report, ongoing UNFCCC negotiations, and based on new scientific analyses.
2. Workshop participants discussed how land-based mitigation measures and their impacts can/could be monitored and assessed by the GCOS Essential Climate Variables (ECVs) beyond national reporting
3. The workshop provided an assessment of users and beneficiaries of improved monitoring of mitigation-relevant variables and recommendations for different stakeholders on how to progress towards that.

An overview of the workshop and all presentation can be found on the web: http://www.wmo.int/pages/prog/gcos/index.php?name=ObservationsforMitigation.

Historically, UNFCCC COP decisions have treated ECVs as providing observational data to improve understanding of the climate system, for example through climate modeling. In addition it is becoming increasingly apparent that there are potential benefits in linking between ECVs and anthropogenic emissions estimation.

In practice this means evolving ECVs such as those related to land cover, soil carbon and biomass to help meet the data needs of the greenhouse gas emissions and removals estimation methodology developed by the Intergovernmental Panel on Climate Change and set out in the Good Practice Guidance of 2000 and 2003, and the 2006 Guidelines [RD-1]. This is because COP decisions require anthropogenic emissions and removals of greenhouse gases, to be estimated and reported using the IPCC methodology, and therefore the effects of mitigation actions need to be quantifiable through the IPCC methodology if they are to count towards national emissions reduction targets agreed under the UNFCCC.

The main priorities for evolving ECVs in this direction are likely to include:

1. Better identification of IPCC land categories (forest land, cropland, grassland, wetlands, settlements, other land) and changes between them.
2. Identification of forestry and agricultural management practices or other human interventions within these categories.
3. Association of carbon densities within sufficiently uniform strata corresponding to the subdivisions identified in 1) and 2) and covering the carbon pools identified by IPCC, namely above and below ground biomass, dead wood, litter and soil organic matter).
4. Identification of extent of transportation and other human infrastructure in so far as these affect the stratification.
5. Identification of disturbance areas, recurrence, and intensities in high carbon ecosystems (e.g. forests and non-forested peatlands).

GCOS anticipates that the benefits of doing this, particularly if ECVs could be linked to socio-economic data, would include better understanding of the relationship between drivers of emissions trends and mitigation potential, and the importance of emerging activities such as agro-forestry.

It became clear that ECVs are not currently targeted for land-based mitigation. For this reason, and as an exploratory initiative, some specific recommendations to better link ECVs and the AFOLU GHG emission estimates (and mitigation reports), would include the following lines of action that have been proposed by the workshop outcomes:

Action 1: Map the requirements from the IPCC AFOLU GPG to the current list of ECVs and associated ECV actions (for the ECVs biomass, land cover, fire, and soil carbon). The ECV actions need to be revised and amended to feed into the IPCC estimations.

Rationale: There is a relationship between ECVs and the UNFCCC reporting based on the guidance for national communications (and therefore based on the UNFCCC conclusions FCCC/SBSTA/2005/10/Paragraph 95 (2005) and FCCC/SBSTA/2007/L.14 (2007) of SBSTA, decision COP 11 and COP 13. Experience in reporting is reflected in the UNFCCC compilation and synthesis reports of national communications. The sixth synthesis report will be provided by COP 20.

Action 2: Take the GFOI/SDCG product list and see how they can be embedded within the current ECV framework.

Rationale: The list from GFOI describes what kind of products are needed, defines the minimal requirements of what is needed, and clarifies what the minimum efforts is on a national level.

Action 3: Investigate the possibility of generating a full global map of land use changes, tracking reported emissions data under the IPCC land use categories. The first step will focus on forest land and forest land changes.

Action 4: Promote better information/data important for mitigation (not covered within the current ECV context) on:

(i) Land management within the land use categories of IPCC, especially forest, agriculture, and livestock.

(ii) Drivers and agents of change (e.g., fire).

(iii) Economic indicators (e.g., infrastructure, settlements, GDP). To what extent should GCOS be active within its mandate?

Action 5: Develop a consistency among mitigation-relevant terrestrial ECVs for IPCC-based estimation and UNFCCC reporting.

Besides a concrete list of actions that have been defined during the workshop and are described in the previous section, there are a series of recommendations addressed to specific stakeholders involved in fostering an increasing links between monitoring ECVs and the evolving needs for climate change mitigation:

- **UNFCCC**

Take note of the efforts by GCOS and its panels to increase the usefulness of ECVs for mitigation and use available mechanisms to underpin this process by additional guidance and priorities, as appropriate, and as international climate negotiations evolve.

- **GCOS**

Include the importance and needs from climate change mitigation in future planning of actions and implementation priorities, definitions and tasks for ECV's, and the allow for continuous engagement with the climate change mitigation user communities and relevant panels such as GOFC-GOLD.

- **Space agencies**

Governments supporting the main agencies in charge of space-based EO programs have confirmed their commitment to ensure continuity of activities that will allow the provision of EO data for the next 20 years to support climate change monitoring and mitigation activities. We recommend space agencies to further develop the coordination of their activities via the Committee on Earth Observation Satellites (CEOS), and to facilitate the access and the use of EO data for climate change mitigation efforts. ESA and NASA, in coordination with other national agencies and research institutes, have been engaging in the development of some terrestrial ECVs following the GCOS requirements. We recommend the space agencies to maintain their participation in these initiatives, to ensure the adequacy of future EO data and associated services considering the evolution of the priorities and needs for the ECVs reported in this document.

4 EVOLVING USERS' REQUIREMENTS

4.1 Key users expectations (surveys Phase 2 – Year 1 & Phase 2 – Year 2)

In this assessment we have implemented a detailed requirements analysis of the LC products delivered by the CCI Land Cover team in Phase 1. Besides the evaluation of these new datasets, the surveyed climate modelling partners have reflected on the requirements for future versions of LC products. A detailed synthesis of the results is provided in Appendix A2: KEY USER SURVEY SYNTHESIS PHASE 2 – YEAR 2.

Key users have focused the analysis in some products and proposed and prioritize the development of new products and products' features. In order to provide a summary of tested/proposed product, stage of development and importance, we prepared Table 4-1, showing how the requirements and product relevance have evolved.

Table 4-1: Summary of tested and requested LC products during Phase I and Phase 2 – Year 1 of the CCI-LC project

Product type	Product	Stage of development	Tested in Phase 2 - Year 2?	Key Users Evaluation or Expectations	Priority for future development
LC maps	2000-2005-2010 maps	Finished	Yes	• Evaluated as moderate to good • Annual temporal resolution is requested	High
	1980's & 1990's maps	In preparation	-	• Annual temporal resolution is requested	High
	Africa high resolution map	In preparation	-	• Further discussion is needed to check advantages of HSR • More LC-PFTs conversion should be achieved	High, since 30 m resolution is a target requirement
Land Surface Seasonality or LC condition products	Vegetation greenness (NDVI)	Finished	Yes	• Evaluated as good • Full time series is requested	High, considering the interest of testing it
	Snow	Finished	No	• Not evaluated	Low, considering the interest of testing it
	Burned areas	Finished	No	• Not evaluated	Low, considering the interest of testing it
	Evapo-transpiration	Prototype	Yes	• Models yielded higher ET values than the CCI-LC ET product • Further testing is needed	Medium
	Vegetation and soil surface albedo	Requested	-	• Number 1 in the priority list	High
	FaPAR	Requested	-	• Number 2 in the priority list	Medium

	Permafrost fraction	Requested	-	• Number 3 in the priority list	Medium
	LAI	Requested	-	• Proposed as an extra product	Low
	Irrigated and wetlands	Requested	-	• Proposed as an extra product	Low
	Soil moisture	Requested	-	• Proposed as an extra product	Low
	Land Surface Temperature	Requested	-	• Proposed as an extra product	Low
Other LC products	MERIS Surface Reflectance	Finished	No	• Not evaluated, but with some interest for future testing	Low, considering the interest of testing it
	Water bodies	Finished	Yes	• With some technical problems on artificial bodies in the coast line • More categories are requested (at least ocean-inland water)	High, to be included as a seasonality LC product
	User tool	Finished	Yes	• Evaluated as good	High, considering it was used by all users

Important considerations for future LC products are:

1. A longer temporal extent (30 years and more) and annual time steps are required to better address the issue of land cover change.
2. Although improvements on the cross walking table have been made and acknowledged by the climate modelling users, still some improvement are requested on deriving more PFTs such as C3-C4 plants, crops, pastures, moss-lichens, etc. However, priorities on a more detailed LC – PFTs classification vary among users, and therefore, further discussion need to be done on this regard.
3. Not all types of land cover change were implemented and were requested by the climate modelers.
4. Additional relevant LC condition products for current climate modelling applications are (order implies priority):
    a. Vegetation and soil albedo
    b. FaPAR
    c. Permafrost fraction
    d. LAI
    e. Irrigated areas and wetlands
    f. Land surface temperature
    g. Soil moisture
5. Additional relevant LC condition products for future climate modelling applications are (order implies priority):
    a. LAI per PFT

b. Forest canopy gaps

c. Seasonal variation of water bodies

4.2 Requirements from climate-related land use and land management community

There are series of scientific community processes and initiatives that aim to provide more specific requirements and synthesis on what data are needed for the next generation of Earth System and Climate modelling. These processes are still ongoing or at least have not provided a final document but are listed here with their initial requirements listed. More relevant inputs from these processes are expected within the next year.

4.2.1 TERRABITES

TERRABITES was a COST action (ES0805) to support the integration of existing knowledge on global biosphere functioning and the expertise in Earth system simulation and observation in current climate change modelling efforts, and this way, forecast the future co-evolvement of climate and biosphere. Such an integrative view is currently missing, since the relevant knowledge is scattered about at least three different, largely separated communities, namely the Earth observation community, the ecological research community, and the climate modelling community. During the time frame of this COST action (2009-2013), TERRABITES organized cross-community workshops, open conferences, and training schools. More details can be found in http://www.terrabites.net/.

TERRABITES participated actively in the Global Vegetation Monitoring and Modeling Conference, which took place in Avignon, France, during 3-7 February 2014. Conclusions of Session 7: ‘Land ECV available products and new products’ are indicated as follows:

1. Geo biochemical products retrieved using earth observation systems are required (e.g. Photochemical Reflectance Index, PRI for GPP and isoprenoid exchange estimations)
2. A consistency check of ESA – CCI land cover products is required
3. Modelling applications should move from PFTs to ecosystem traits.
4. A global vegetation water content product is required.
5. The need for a higher spatial detail of LC products (> 100 m) has to be revised

4.2.2 International Space Science Institute (ISSI)

The ‘Integrating Earth Observation’ team for data and the description of land management has defined as a task to ‘develop appropriate modeling concepts to incorporate the EO and census information in global scale land vegetation/carbon cycle models’. More details can be found in this website: http://www.issibern.ch/teams/carboncyclemodels/index.htm

To achieve this task, the ISSI Integrating Earth Observation team is addressing the following issues:

1. Assess and quantify the scale and importance of different land management activities, such as irrigation, fertilizer application, stocking rates in order to decide on possible model restructuring (e.g. the development of new land cover related functional entities).
2. Prioritize the processes that need to be incorporated in Earth System Models (ESMs) to account for land management activities.

On 17th-19th February 2014, a working group on land management, consisting of climate modelers and earth observation experts, were meeting at ISSI in Bern, Switzerland. The goal was to identify land data requirements of the climate research community, both for current and future developments. This comprised input data for climate models but also data for evaluation. A questionnaire was prepared and sent out in May 2014 to all major modelling communities in order to assess their current data requirements and those for the next few year (up to 5+ yrs). In total ca. 15 Earth System Model (ESM), 5 Land Surface Model (LSM) and 5 Integrated Assessment Model (IAM) groups were contacted, of which 15 replied to the questionnaire.

Besides questions about features and data requirements of the different models on land management, greenhouse gases and ecological parameters, the questionnaire was inquiring about the implementation and consideration of land changes in the different models. Two questions were relevant with respect to land change implementations:

- Does the model consider sub-grid transitions, like gross land changes? and
- What are the most important data requirements, now and in the coming 5 years?

Concerning the first question, sixteen modelling groups gave an answer whether they are currently capable to consider gross land changes in their models or not. Up to now 37.5% of the models are able to consider gross land changes. However, in the next 1-4 years ca. 72% of the modelling groups want to have gross land changes implemented in their models. This demonstrates the increasing need for gross land change data. But it also shows that the different modelling communities are well aware of the importance of the full dynamics of land change processes and their relevance for climate change related questions.

It is hard to say if the availability of land change data in the end triggered the modelling community to implement gross land changes or if it was the other way around, but before the Coupled Model Intercomparison Project Phase 5 (CMIP5) gross changes were hardly implemented in ESMs. However, since a couple of years, up to 33% of the models implemented gross changes. For the upcoming CMIP6, so in the next 1-4 years, the demand for gross change data will further increase.

While question one was explicitly asking for the willingness/capabilities to implement gross land changes, question two was meant to be an open question, where climate modelers could fill in any type of required data. In total 60% of the modelling groups mentioned ‘better land cover/use data’ and another 40% required ‘land change data with gross land change transitions’ (Figure 4-1Figure 4-1: Data requirements for global Earth System Models (ESMs), Land Surface Models (LSMs), and Integrated Assessment Model (IAMs), separated for three different periods (present, in 1-4 years and in 5 years).). Gross land cover/use change data was the most frequent answer of all the data requirements.

Concerning the second question, the ISSI questionnaire 2014 showed that models will increasingly consider: i) land cover/ land use change and ii) land change management for distinctive LC types (e.g. forest, crops, pastures). As shown by Figure 4-2, management activities related to agriculture (highlighted in red) and especially those related to the N/P cycling, fire and other GHG (highlighted in green) will be relevant for future modeling efforts.

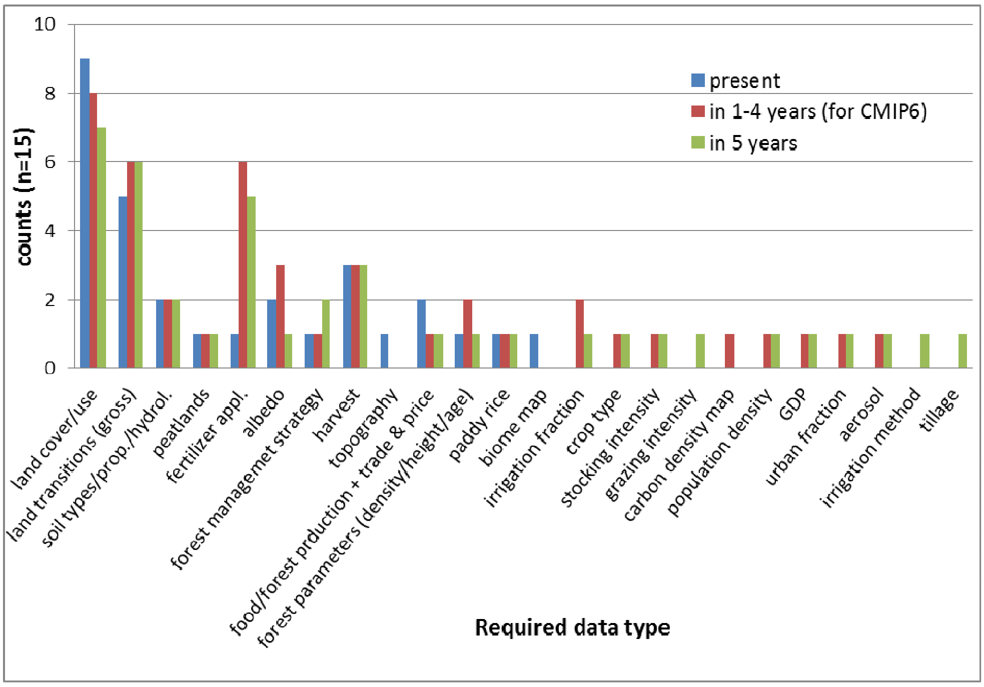

Figure 4-1: Data requirements for global Earth System Models (ESMs), Land Surface Models (LSMs), and Integrated Assessment Model (IAMs), separated for three different periods (present, in 1-4 years and in 5 years).

4.2.3 The Coupled Model Intercomparison Project, Phase 6 (CMIP6)

Coupled Model Intercomparison Project (CMIP) is entering round 6 for the next IPCC assessment report. CMIP 6 will put particular emphasis to improve the role and integration of land use land management. A survey of the CMIP5 experiments showed that:

- Land use implementations vary a lot from model to model, which has a big impact on C changes
- Aerosol and land use future scenarios did not span uncertainty range
- No scientific check on consistency across datasets (e.g. does the land-use forcing match the biomass burning forcing regionally?) has been performed

The CMIP 6 exercise is expected to use more land cover/use and land management data a user needs survey emphasizes the future priorities by the modeling groups. These priorities areas largely relate to including additional processes and, thus requiring additional datasets and information. According to the results of the ISSI survey of 14 ESM models, the following trends can be observed:

- Variables related to Land cover/use change, fire and harvest (wood and crops) are already considered in several modeling frameworks and will continue to grow in importance.
- Processes and variables related to Nitrogen & Phosphorous cycling, more wood-related information (i.e. age classes) and GHG gases other than CO2 (CH4 and N2O) are currently not well represented but will grow in significantly grow in importance.
- Information related to agriculture and pasture management are currently rarly used and are generally of lower priority than the other variables.

These developments highlight the importance of land use and land management in the future of ESM (Figure 4-2).

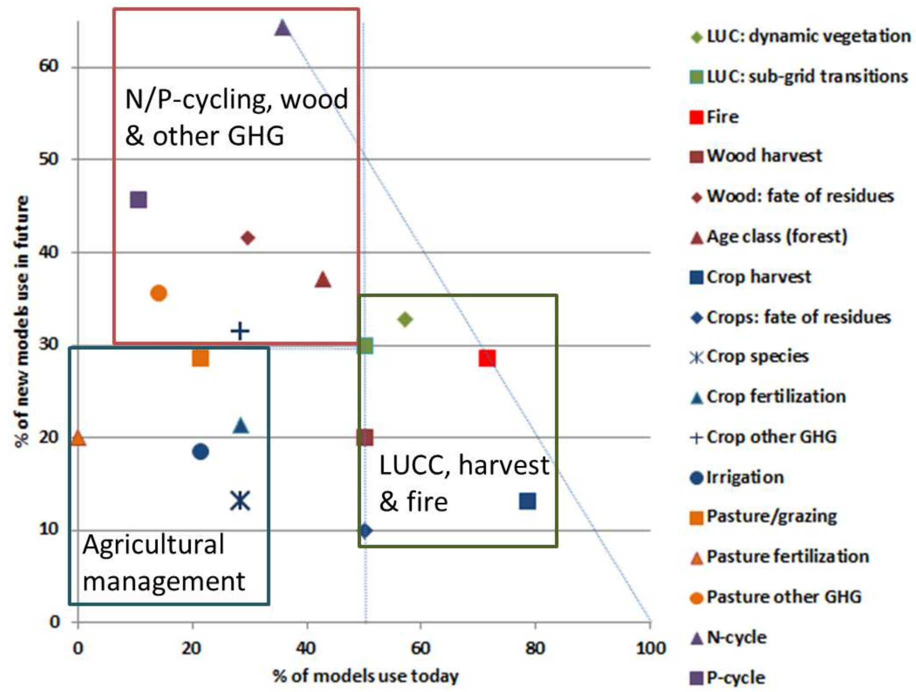

Figure 4-2: Anticipated use of new processes in CMIP 6 models versus use in CMIP 5 (Source: [RD-2])

4.3 Requirements for long-term land cover reconstructions

The recent IPCC Assessment Report 5 (fully released in April 2014) has emphasized the importance of the land use change in the global carbon cycle. In fact the land use flux remains the most uncertain part in the global anthropogenic CO_2 budget (Table 4-2).

Table 4-2: Global anthropogenic CO2 budget, accumulated since the Industrial Revolution (onset in 1750) and averaged over the 1980's, 1990's, 2000's, as well as the last 10 years until 2011. Source: [RD-2].

	1750–2011 Cumulative PgC	1980–1989 PgC yr⁻¹	1990–1999 PgC yr⁻¹	2000–2009 PgC yr⁻¹	2002–2011 PgC yr⁻¹
Atmospheric increase[a]	240 ± 10[f]	3.4 ± 0.2	3.1 ± 0.2	4.0 ± 0.2	4.3 ± 0.2
Fossil fuel combustion and cement production[b]	375 ± 30[f]	5.5 ± 0.4	6.4 ± 0.5	7.8 ± 0.6	8.3 ± 0.7
Ocean-to-atmosphere flux[c]	–155 ± 30[f]	–2.0 ± 0.7	–2.2 ± 0.7	–2.3 ± 0.7	–2.4 ± 0.7
Land-to-atmosphere flux *Partitioned as follows*	30 ± 45[f]	–0.1 ± 0.8	–1.1 ± 0.9	–1.5 ± 0.9	–1.6 ± 1.0
Net land use change[d]	180 ± 80[f,g]	1.4 ± 0.8	1.5 ± 0.8	1.1 ± 0.8	0.9 ± 0.8
Residual land sink[e]	–160 ± 90[f]	–1.5 ± 1.1	–2.6 ± 1.2	–2.6 ± 1.2	–2.5 ± 1.3

When looking in more detail on the data sources used to estimate of net land to atmosphere flux from land use change, Table 4-3 highlights that these rely on land cover information that have longer-term information. These come from AVHRR data records, country reported data and land cover reconstructions (such as HYDE). In the estimation they are basically averaged to provide the global and regional results.

Table 4-3: Data sources and estimates of net land to atmosphere flux from land use change (PgC yr-1, except where noted) for decadal periods from 1980's to 2000's by region. Source: [RD-2].

	Land Cover Data	Central and South Americas	Africa	Tropical Asia	North America	Eurasia	East Asia	Oceania
2000s								
van der Werf et al. (2010)[a,b]	GFED	0.33	0.15	0.35				
DeFries and Rosenzweig (2010)[c]	MODIS	0.46	0.08	0.36				
Houghton et al. (2012)	FAO-2010	0.48	0.31[e]	0.25	0.01	–0.07[d]	0.01[e]	
van Minnen et al. (2009)[a]	HYDE	0.45	0.21	0.20	0.09	0.08	0.10	0.03
Stocker et al. (2011)[a]	HYDE	0.19	0.18	0.21	0.019	–0.067	0.12	0.011
Yang et al. (2010)[a]	HYDE	0.14	0.03	0.25	0.25	0.39	0.12	0.02
Poulter et al. (2010)[a]	HYDE	0.09	0.13	0.14	0.01	0.03	0.05	0.00
Kato et al. (2013)[a]	HYDE	0.36	–0.09	0.23	–0.05	–0.04	0.10	0.00
Average		0.31 ± 0.25	0.13 ± 0.20	0.25 ± 0.12	0.05 ± 0.17	0.12 ± 0.31	0.08 ± 0.07	0.01 ± 0.02
1990s								
DeFries et al. (2002)	AVHRR	0.5 (0.2–0.7)	0.1 (0.1–0.2)	0.4 (0.2–0.6)				
Achard et al. (2004)	Landsat	0.3 (0.3–0.4)	0.2 (0.1–0.2)	0.4 (0.3–0.5)				
Houghton et al. (2012)	FAO-2010	0.67	0.32[e]	0.45	0.05	–0.04[d]	0.05[e]	
van Minnen et al. (2009)[a]	HYDE	0.48	0.22	0.34	0.07	0.08	0.20	0.07
Stocker et al. (2011)[a]	HYDE	0.30	0.14	0.19	–0.072	0.11	0.27	0.002
Yang et al. (2010)[a]	HYDE	0.20	0.04	0.31	0.27	0.47	0.19	0.00
Poulter et al. (2010)[a]	HYDE	0.26	0.13	0.12	0.07	0.16	0.11	0.01
Kato et al. (2013)[a]	HYDE	0.53	0.07	0.25	–0.04	–0.01	0.16	0.02
Average		0.41 ± 0.27	0.15 ± 0.15	0.31 ± 0.19	0.08 ± 0.19	0.16 ± 0.30	0.16 ± 0.13	0.02 ± 0.05
1980s								
DeFries et al. (2002)	AVHRR	0.4 (0.2–0.5)	0.1 (0.08–0.14)	0.2 (01–0.3)				
Houghton et al. (2012)	FAO-2010	0.79	0.22[e]	0.32	0.04	0.00[d]	0.07[e]	
van Minnen et al. (2009)[a]	HYDE	0.70	0.18	0.43	0.07	0.06	0.37	0.04
Stocker et al. (2011)[a]	HYDE	0.44	0.16	0.25	0.085	0.11	0.40	0.009
Yang et al. (2010)[a]	HYDE	0.26	0.01	0.34	0.30	0.71	0.59	0.00
Poulter et al. (2010)[a]	HYDE	0.37	0.11	0.19	0.02	0.03	0.29	0.01
Kato et al. (2013)[a]	HYDE	0.61	0.07	0.25	–0.04	–0.02	0.35	0.01
Average		0.51 ± 0.32	0.12 ± 0.12	0.28 ± 0.14	0.08 ± 0.19	0.15 ± 0.46	0.35 ± 0.28	0.01 ± 0.03

A series of different historic reconstructions of land cover/use has been published and applied in different assessments. Many of these reconstructions have global coverage and span several centuries and millennia ([RD-3], [RD-4], [RD-6], [RD-7]). Current reconstruction approaches have coarse spatial resolution (0,5-2,5 degrees) and rely mostly on land cover/use databases containing country level statistics of the last 50 years, mainly those collected by the Food and Agriculture Organization (1961 to present). These national level statistics are used to calculate spatial maps of historic land use. Strong assumptions are made to fill data gaps and identify sub-national patterns of land cover. For example, the frequently used HYDE data base ([RD-5], [RD-6]) allocated historic cropland, pastures and urban area based on per capita land use estimates and population maps, after using FAO inventories for calibration of the per capita land use areas. Current global reconstructions of historic land cover/use provide valuable estimates of land cover/use for a certain historic period, but do not give detailed insights into the dynamic changes in land cover/use that may have taken place over time. Most reconstructions are based on the difference in land cover/use areas between two time steps (net changes) as given by FAO data. By nature these net change estimates deviate from the sum of all area gains and losses in the area of the different land use types (gross changes). Only accounting for the net changes can lead to serious underestimation of the land use changes, which may have implications for biogeochemical, ecological and environmental assessments.

The need to account to better as for gross land changes, and the inherent uncertainties in land cover reconstructions emphasize the need to increase the database for longer-term land cover reconstructions calls for better input from the remote sensing data record to provide consistent-long term land cover observations, for a few key classes and sufficient on coarser spatial resolutions.

5 OVERVIEW OF LAND COVER ECV USER REQUIREMENTS PHASE 2

Land Cover has been selected as one of the ECVs which will be elaborated during the Phase 1 and Phase 2 of the ESA Climate Change Initiative. In order to provide a comprehensive overview of the user requirements for the different ECVs, ESA has provided a standard template for presentation. Below the summary for the LC user requirements is provided according to this template.

5.1 Product Characteristics & Attributes

- **User Name; Affiliation**

ESA–CCI Land Cover project user assessment team (lead Wageningen University)

- **ECV Name**

Land Cover

- **Parameter Standard Name**

Land Cover

- **Definition**

Land cover refers to the physical and biological cover over the surface of land, including water, vegetation, bare soil, and/or artificial structures (Di Gregorio, 2005).

- **Units:**

UN–LCCS classifiers and PFT thematic definitions (flexibility to feed into different models) and changes between key land categories

- **Projection**

The land cover products will be projected in a Plate-Carrée projection with a geographic Lat/Long representation (WGS84 ellipsoid). The coordinates will be specified in degrees/minutes/seconds. Possibility to reproject the land cover product to model-specific projections should be included.

- **Processing Level**

Level 4 (i.e. global land cover map at the full spatial resolution)

- **Metadata**

An XML document with a well-defined schema (CMUG to help to specify) which clearly defines the satellite data, processing, measurement and monitoring techniques and the analysis method and quality information used to retrieve the data record. Specific requirements include: 1) validation information: specific areas which were checked with in situ data, and level of agreement with other land cover datasets; 2) clear description of classification methodology and underlying assumptions (e.g., cloud and snow mask); 3) information to support assessment of consistency with other EO derived products (e.g., albedo, vegetation-biophysical variables).

- **Format**

NetCDF and GeoTIFF

- **Usage & Application**

1. Parameterization of several land surface parameters assigned based on Plant Functional Types (PFTs);
2. Trend monitoring and tracking human activities, i.e. land use affecting land cover;
3. Validation of model outcomes (i.e. time series) or to study feedback effects.

5.2 Quantitative Requirements

At least two levels of requirement should be identified:

- **Threshold requirement**: the limit at which the observation becomes ineffectual and is not of use for the climate-related application.

- **Target requirement**: the maximum performance limit for the observation, beyond which no significant improvement would result for climate applications.

Table 5-1: Updated threshold (minimum) and target (optimal) requirements identified for LC products in the User Requirements Survey carried out in the CCI–LC project Phase 2 – Year 1.

	Threshold requirement Phase 2	Target requirement Phase 2
	Coverage and sampling	
Geographic Coverage	Global with regional specific products	Global with regional specific products
Temporal sampling	5-10 year epoch maps with monthly vegetation dynamics (NDVI)	1-year epoch maps. Monthly data on Vegetation dynamics (NDVI)
Temporal extent	1990 (or earlier) -present	1980 (or earlier) - present
	Resolution	
Horizontal Resolution	300 m with regional 30 m products	30 m
Vertical Resolution		

	Threshold requirement Phase 2	Target requirement Phase 2
	Error/Uncertainty	
Precision	Thematic land cover detail (incl. conversion tables to PFT for climatic regions) sufficient to meet current and future model needs, incl. key land IPCC changes	Thematic land cover detail (incl. conversion tables to PFT for climatic regions) and traits) sufficient to meet current and future model needs, incl. land changes and land management
Accuracy	Higher accuracy than existing datasets	Errors less than 5-10% either per class or as overall accuracy
Stability	Higher stability than existing datasets	Errors less than 5-10% either per class or as overall accuracy
Error Characteristics	Independent multi-date validation	Operational and independent multi-date validation

- **Ancillary Requirements**

Land cover has been and remains a fundamental dataset as consistent input to climate models and for the integration of other data sources. There is a need for both stable land cover data and a dynamic component (land changes) and increasingly longer time spans. Consistency among the different model parameters (derived from land cover and other data sources) and among different terrestrial ECV's is often more important than accuracy of individual datasets

- **Requirement Rationale & Traceability:**

In the Phase 1 of the CCI–LC project, detailed user specifications have been derived through a comprehensive user consultation mechanism for a global land cover product will be defined which matches the requirements from GCOS (both for itself and as a surrogate for other important climate variables) and key climate users, and which is achievable on a regular basis using the current EO systems and building on the UN–LCCS for consistency and interoperability with other land cover products. The results have been described and published [AD-1].

To update and revise the requirements, a survey to gather climate modeling user feedback from the Phase 1 have been performed. An engagement with scientific community and the results of the recent IPCC assessment report 5 have been analyzed to capture evolving requirements from the scientific community. The evolving GCOS requirements, in particular for linking ECV's more to the needs of climate change mitigation, have been documented and included in the user assessment.

6 APPENDIX

6.1 A1: KEY USER SURVEY PHASE 2 – YEAR 2

6.1.1 General information

6.1.1.1 Name and institution/organization of whom completed the survey:

6.1.1.2 Which climate model(s) and version(s) have you used / are you planning to use in the context of ESA CCI Land Cover project?

Period/milestone	**Model/version**
Before May 2013	
May 2013: internal release of the 3 global land cover maps and condition products	
May 2013 - Feb 2014	
Feb 2014 Launch of Phase 2	
Feb 2014 - March 2015	
March-Dec 2015	
2016	

6.1.1.3 Which of the following ESA-CCI land cover products have you recently used (Feb 2014 - March 2015) for your specific model application?

Product 1: global land cover maps

Global land cover map 2010

Global land cover map 2005

Global land cover map 2000

Product 2: land surface seasonality products

NDVI

Snow occurrence

Burned areas

Product 3: global map of open permanent water bodies

SAR-based water bodies product

Product 4: full archive of MERIS time series

7-day composites of MERIS surface reflectance (2003-2012)

Product 5: User tool for re-projecting, re-sampling and converting the products into climate model inputs

User tool

If you used the user tool, could you specify the version?_________________

6.1.2 ESA-CCI Global Land Cover maps

6.1.2.1 How would you estimate the accuracy of the ESA-CCI land cover maps for your current application case?

Please mark your choice with an X

	Poor <65% sufficient	**Moderate 65-80% sufficient**	**Good 80-90% sufficient**	**Very good 90-100% Sufficient**
Global land cover map 2010				
Global land cover map 2005				
Global land cover map 2000				

6.1.2.2 How do you evaluate the consistency of the ESA-CCI land cover maps with your current model requirements?

Please mark your choice with an X

	Rather insufficient	**With some problems**	**Sufficient**
Global land cover map 2000			
Global land cover map 2005			
Global land cover map 2010			

6.1.2.3 How do you evaluate the following features of the ESA-CCI land cover products according to your current modelling application/requirements?

Feature	**Rather insufficient**	**With some problems**	**Sufficient**	**Why?**
Spatial detail (300x300 m)				
Temporal frame (2000-2010)				
Temporal resolution (5 yearly land cover data)				

Feature	Rather insufficient	With some problems	Sufficient	Why?
Land cover categories				
Land cover change categories				
Cross walking table				

6.1.2.4 Did you use the quality flags?

Yes

No

If not, explain the reason, if yes, explain which quality flags you used and how you used them:

6.1.2.5 Which format did you use?

NetCDF

GeoTIFF

Both

6.1.2.6 Was the projection (lat/long) of the global maps compatible with your modelling application?

Yes

No

If not, explain the reason, if yes, explain how you used them:

6.1.2.7 In your opinion, which aspects of the CCI-LC maps would need to be improved? Explain in the corresponding table cells.

Dimensions of CCI-LC global maps	Improvements (in your opinion)
Accuracy	
Consistency	
Spatial detail (300x300m)	
Temporal resolution (5 yearly)	

Dimensions of CCI-LC global maps	Improvements (in your opinion)
Temporal extent (2000-2010)	
Land cover categories	
Type of land cover change	
Quality flags, metadata and format	

6.1.2.8 In the specifications of the next version of the maps, LC change between epochs should focus on the main IPCC land categories. They are listed in the table as follows. Please indicate the order of priority between these classes.

Please give one number to each attribute (from 1 - highest priority to 6 - lowest priority).

IPCC land category	Priority order
Forest	
Agriculture	
Grassland	
Settlement	
Wetland	
Other land	

6.1.2.9 In the specifications of the next version of the maps, new attributes have been identified as relevant for modelling applications. They are listed in the table as follows. Please indicate the order of priority of including these attributes in the future.

Please give one number to each attribute (from 1 - highest priority to 7 - lowest priority).

LC attributes	Priority order
Vegetation height	
Minimum and maximum Leaf Area Index (LAI)	
Clumping index	
Distinction between C3 and C4 plants	
Aboveground biomass	
Vegetation density	
Land Management	

6.1.2.10 What are your expectations for the new global land cover maps, CCI-LC is elaborating during Phase 2 of the project (2014-2016)?

Explain in the corresponding table cells.

Upcoming global land cover maps	Expectations
Global land cover map for the 1980s	

Global land cover map for the 1990s	

6.1.2.11 A land cover map at high resolution (HR) (10 m) over Africa is being elaborated during Phase 2 of the project (2014 - 2016).

Please, give here your opinion towards the following aspects of this map:

<table>
<tr><td>Upcoming aspects of HR LC map</td><td colspan="2"></td></tr>
<tr><td rowspan="7">A hierarchical legend at high resolution (10 m) would be provided first at a level of 5 LC classes and then at a second level of no more than 10 classes</td><td colspan="2">What are your expectations regarding the concept of hierarchical legend?

What would be the 5 level 1 and level 2 classes of interest?</td></tr>
<tr><td>Level 1 classes</td><td>Level 2 classes (max 10 classes)</td></tr>
<tr><td>1.</td><td>……………………………………………
……………………………………………
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<tr><td>2.</td><td>……………………………………………
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<tr><td>3.</td><td>……………………………………………
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<tr><td>4.</td><td>……………………………………………
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<tr><td>5.</td><td>……………………………………………
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……………………………………………</td></tr>
<tr><td>Change detection at HR</td><td colspan="2">Establish priorities for the area of change and LC classes of interest for the evaluation of change trajectories</td></tr>
</table>

6.1.3 ESA-CCI land cover seasonality products

6.1.3.1 How do you use or have used the seasonality products in your modelling application?

Please mark your choice with an X

	As a proxy for land surface parameters	Proxy for human activities	Validation of model outputs	Other (please indicate)
NDVI				
Snow occurrence				
Burned areas				

6.1.3.2 Did you experience problems when using the seasonality products in your modelling application? If yes, what were they?

If you have used these products for more than one purpose (as indicated in question 3.1), please indicate the problems for each purpose in separate tables.

NDVI	Snow occurrence	Burned areas
Have you experienced problems? Yes T No	Have you experienced problems? Yes No	Have you experienced problems? Yes No
If yes, please explain:	If yes, please explain:	If yes, please explain:

6.1.3.3 How do you evaluate the consistency of the land cover seasonality products with others CCI-LC products?

Please mark your choice with an X

	I did not check consistency with this product	Rather insufficient	With some problems	Sufficient
Consistency among seasonality products				
Consistency with global land cover maps				
Consistency with MERIS surface reflectance time series				
Consistency with the global water bodies product				

6.1.3.4 Did you use the quality flags?

Yes

No

If not, explain the reason, if yes, explain which quality flags you used and how you used them:

6.1.3.5 What would be the key aspects for future improvements of the ESA-CCI land cover condition products for your modelling application?

Explain in the corresponding table cells.

NDVI	Snow occurrence	Burned areas

6.1.3.6 During this year, you received a prototype seasonality product about evapotranspiration. Did you test it?

Yes

No

6.1.3.7 If you tested the Evapotranspiration product, could you summarize your experience? If not, explain the reason.

6.1.3.8 In the previous survey, some additional seasonal (or LC condition) products were identified as relevant for modelling applications. They are listed in the table as follows. Please indicate the order of priority of including these products in the future.

Please give one number to each attribute (from 1 to 4).

Seasonal products	Priority order
FaPAR	
Permafrost fraction	
Vegetation and soil surface albedo	

6.1.3.9 Which other land cover seasonality products would be relevant for your current and future modelling application?

Explain in the corresponding table cells.

Current modelling application:
Future modelling application:

6.1.4 ESA-CCI MERIS surface reflectance time series

6.1.4.1 Did you use the MERIS surface reflectance time series in your modelling application?

Yes

No

6.1.4.2 If you used the MERIS surface reflectance time series in your modelling application, how did you use it?

Please mark your choice with an X

	As a proxy for land surface parameters	Proxy for human activities	Validation of model outputs	Other (please indicate)
MERIS surface reflectance time series				

6.1.4.3 What were the main problems when using MERIS surface reflectance time series in your modelling application?

If you have used this product for more than one purpose (as indicated in question 4.1), please indicate the problems for each purpose.

Purpose 1: ___________	Purpose2: ___________	Purpose3: ___________
Have you experienced problems? Yes No	Have you experienced problems? Yes No	Have you experienced problems? Yes No
If yes, please explain:	If yes, please explain:	If yes, please explain:

6.1.4.4 Did you use the quality flags?

Yes

No

If not, explain the reason, if yes, explain which quality flags you used and how you used them:

6.1.4.5 How do you evaluate the consistency of MERIS surface reflectance time series with others CCI-LC products?

Please mark your choice with an X

	I did not check consistency with this product	Rather insufficient	With some problems	Sufficient
Consistency with seasonality products				

Consistency with global land cover maps				
Consistency with the global water bodies product				

6.1.4.6 *In the future, do you plan to use the ESA-CCI MERIS surface reflectance time series for your modelling application?*

Yes

No

6.1.4.7 *If you plan to use it, what would be the key aspects for future improvements of the ESA-CCI MERIS surface reflectance time series for your modelling application?*

6.1.5 ESA-CCI global water bodies

6.1.5.1 *How do you use or have used the ESA-CCI global water bodies product in your modelling application?*

Please mark your choice with an X

	As a proxy for land surface parameters	Proxy for human activities	Validation of model outputs	Other (please indicate)
Global water bodies				

6.1.5.2 *Did you experience problems when using the global water bodies product in your modelling application? If yes, what were there?*

If you have used this product for more than one purpose (as indicated in question 5.1), please indicate the problems for each purpose.

Purpose 1:___________	Purpose2: ____Validation_______	Purpose3: ___________
Have you experienced problems? Yes No	Have you experienced problems? Yes No	Have you experienced problems? Yes No
If yes, please explain:	If yes, please explain:	If yes, please explain:

6.1.5.3 Did you use the extra NObsImsWS and NObsImsGM bands?

NObsImsWS band (Number of observations originating from the ASAR WSM + IMM imagery)	**NObsImsGM band** (Number of observations originating from the ASAR global monitoring mode imagery)
Yes No	Yes No

If not, explain the reason, if yes, explain which quality flags you used and how you used them:

NObsImsWS band	**NObsImsGM band**

6.1.5.4 How do you evaluate the consistency of the global water bodies product with others CCI-LC products?

Please mark your choice with an X.

	I did not check consistency with this product	**Rather insufficient**	**With some problems**	**Sufficient**
Consistency with seasonality products				
Consistency with global land cover maps				
Consistency with MERIS surface reflectance time series				

6.1.5.5 What would be key aspect for future improvements of the global water bodies product for your modelling application?

Please mark your choice with an X

	Water bodies dynamics	**More detailed typology (e.g. lakes, river, ocean)**	**Higher spatial Resolution**	**Other (please indicate)**
Global water bodies				

If you have specific aspects for future improvements, please indicate as follows:

6.1.6 User tool

6.1.6.1 Did you use the reprojection and class agregation tool of the ESA-CCI land cover data?

Yes

No

If yes, which version? _____________

If yes, on which products? _____________

If no, explain the reason.

6.1.6.2 Was the reprojection and class agregation tool useful?

Yes

No

If no, explain the reason.

6.1.6.3 Did you use the LC class – PFTs convertion tool?

Yes

No

If no, explain the reason.

If yes, did you use:

The default cross-walking table?

A user-defined cross walking table?

6.1.6.4 How do you evaluate the functionalities of the user tool?

Please mark your choice with an X

	I did not check this functionality	Rather insufficient	With some problems	Sufficient
Ranking of LC class by fractional area in target cell				
Fractional area of each LC class				
Fractional area of each PFT				
Reprojection				

6.1.6.5 What would be key aspect for future improvements of the user tool for your modelling application?

Please mark your choice with an X

	Distinction between C3/C4 plants	Biomes delineation	Other (please indicate)
User tool			

If you have specific aspects for future improvements, please indicate as follows:

6.1.7 Communication between ESA-CCI land cover producers and users

6.1.7.1 How would you judge the communication between data producers and users?

Please mark your choice with an X

Sufficient

With some problems

Rather insufficient

There was no communication at all

6.1.7.2 How could the communication be improved? Please explain.

6.1.7.3 Which of the following reports accompanying the ESA-CCI land cover products did you use or have used in your modelling application?

Please mark your choice with an X

Report	Short name	Link
Algorithm theoretical basis document	ATBD	http://www.esa-landcover-cci.org/?q=webfm_send/59
Climate assessment report	CAR	http://www.esa-landcover-cci.org/?q=webfm_send/62
Data access requirements document	DARD	http://www.esa-landcover-cci.org/?q=webfm_send/52
Detailed processing model	DPM	http://www.esa-landcover-cci.org/?q=webfm_send/55
Input output data description	IODD	http://www.esa-landcover-cci.org/?q=webfm_send/56
Internal preliminary validation report	IPVR	http://www.esa-landcover-cci.org/?q=webfm_send/57
Product specification document	PSD	http://www.esa-landcover-cci.org/?q=webfm_send/51
Product validation and Inter-comparison report	PVIR	http://www.esa-landcover-cci.org/?q=webfm_send/63
Product validation plan	PVP	http://www.esa-landcover-cci.org/?q=webfm_send/44
System prototype description	SPD	http://www.esa-landcover-cci.org/?q=webfm_send/53
System requirements document	SRD	http://www.esa-landcover-cci.org/?q=webfm_send/45
System specification document	SSD	http://www.esa-landcover-cci.org/?q=webfm_send/58

Report	Short name	Link
System verification report	SVR	http://www.esa-landcover-cci.org/?q=webfm_send/54
User requirements document	URD	http://www.esa-landcover-cci.org/?q=webfm_send/46

6.1.7.4 How would you judge the reports accompanying the ESA-CCI land cover products?

Please mark your choice with an X

Report (short name[1])	Not useful	Useful	Very useful
ATBD			
CAR			
DARD			
DPM			
IODD			
IPVR			
PSD			
PVIR			
PVP			
SPD			
SRD			
SSD			
SVR			
URD			

6.1.7.5 How could the reporting be improved? Please explain.

[1] See question 6.1.7.3 for the acronyms definition

6.1.8 Final remarks

6.1.8.1 Please indicate any final remark you consider relevant to include in the Third Key User Requirements Report (Phase 2 - Year 2).

6.2 A2: KEY USER SURVEY SYNTHESIS PHASE 2 – YEAR 2

1 General information

1.1 Participants

MOHC	Met Office Hadley Centre
MPI	Max Planck Institute for Meteorology
LSCE	Laboratoire des Sciences du Climat et de'l Environnement

1.2 Climate models

	Period				
	Before May 2013	***May 2013 - Feb 2014***	***Feb 2014 - March 2015***	***March-Dec 2015***	***2016***
MOHC	JULES v3.2C	JULES v3.2C	JULES v3.2C	JULES v4.2	JULES v4.3
MPI-M	JSBACH 2	JSBACH 2	JSBACH 3.0	JSBACH 3.0	JSBACH
LSCE	IPSL ESM – ORCHIDEE LSM vAR5	IPSL ESM – ORCHIDEE LSM vAR5	IPSL ESM – ORCHIDEE LSM vAR5	IPSL ESM – ORCHIDEE LSM Trunk (current version)	IPSL ESM – ORCHIDEE LSM Trunk (current version)

1.3 ESA-CCI land cover products

Product 1: Land Cover Maps

Land cover map 2000	MOHC-MPI-LSCE (100%)
Land cover map 2005	MOHC-MPI-LSCE (100%)
Land cover map 2010	MOHC-MPI-LSCE (100%)

Product 2: Land Surface Seasonality products

Vegetation greenness	MPI-LSCE (66%)
Snow occurrence	Not used (0%)
Burned areas occurrence	Not used (0%)

Product 3: Water bodies

Water bodies	MOHC-MPI (66%)

Product 4: MERIS surface reflectance

MERIS surface reflectance	Not used (0%)

Product 5: User tool

User tool	MOHC-MPI-LSCE (100%)

Version used:
MOHC v3.7 & v3.9
MPI v3.0, v3.3, v3.7 & v3.9
LSCE v3.1, v3.7 & v3.9

2 ESA-CCI Land Cover Maps

2.1 Accuracy of Land Cover Maps

	Poor	Moderate	Good	Very good
Land cover map 2000		LSCE (33%)	MOHC-MPI (66%)	
Land cover map 2005		LSCE (33%)	MOHC-MPI (66%)	
Land cover map 2010		LSCE (33%)	MOHC-MPI (66%)	

2.2 Consistency of Land Cover Maps

	Rather insufficient	With some problems	Sufficient
Land cover map 2000		MOHC-MPI (66%)	LSCE (33%)
Land cover map 2005		MOHC-MPI (66%)	LSCE (33%)
Land cover map 2010		MOHC-MPI (66%)	LSCE (33%)

2.3 Features of the ESA-CCI Land Cover Maps

Feature	Rather insufficient	With some problems	Sufficient	Why?
Spatial detail (300x300 m)			MOHC-MPI – LSCE (100%)	- Models are rarely higher resolution than this - We work with fractional coverages where the highest resolution used is 0.5° so that 300m currently is absolutely sufficient. - Mostly we aggregate to a higher spatial resolution
Temporal frame (2000-2010)		MOHC-MPI - LSCE (100%)		- 2000-2010 is a good start, but it would be more useful to extend this over the full satellite era - Longer period (at least 30 years) will be much appropriate for climate application - If the maps could be extended further back in time or until 2015 that would be better
Temporal resolution (5 yearly land cover data)	LSCE (33%)	MOHC (33%)	MPI (33%)	- Again, a good start, but it would be more useful if this was annual - Natural land cover probably does not change that much on the time scale of 5 years - Annual LC maps needed with LC changes

Land cover categories		MOHC-MPI – LSCE (100%)		- Generally, these are sufficient, but C3/C4 grass distinction would be useful, and help improve consistency between modelling groups. Also, would be nice to see a detailed LCCS description of classes so that vegetation height can be derived - Our model has some PFTs (crops, pasture, rain green shrubs) that do not exist in LC classification - Still issues to sort out to have a better conversion between LC classes and PFTs used in LSMs
Land cover change categories	MOHC (33%)	MPI- LSCE (66%)		- In order to run transient land use simulations, we need change between more classes. - - Not all LC change implemented yet
Cross walking table		MOHC-MPI – LSCE (100%)		- Regional variations could be included following consultation with mapping experts - As noted above, for our model it will be useful to have some additional PFTs (crops, pasture, rain green shrubs), another wish is to have climate classification and C3/C4 photosynthetic pathways implemented into the user tool - Still issues to sort out to have a better conversion between LC classes and PFTs used in LSMs

2.4	**Did you use quality flags?**		**Reasons**
	Yes	0%	- Didn't have time to look at these
	No	MOHC-MPI-LSCE (100%)	- Indirectly, I assume quality flags enter alternative maps that were produced for common climate uncertainty study. However, I have not been using quality flags, because I was not sure how to interpret them. - We have not considered this source of uncertainty yet
2.5	**Which format did you use?**		
	NetCDF		LSCE (33%)
	GeoTIFF		0%
	Both		MOHC - MPI (66%)
2.6	**Projection (lat/long) compatible?**		**Reasons**
	Yes	MOHC-MPI-LSCE (100%)	- - We used output of lc-user-tool either on lon-lat grid or Gaussian grid.
	No	0%	

2.7 Aspects of the CCI-LC maps to be improved

Dimension	Improvements (in your opinion)
Accuracy	- I think this is good compared to other LC maps - I do not have much experience with other LC maps, so I cannot comment on that. - Greater accuracy would be better but we need to fully understand the impact of the accuracy on the derivation of PFTs before being able to fully answer how much this needs to be improved
Consistency	- Perhaps consistency is too high – ie it would be nice to see more LC changes (but only if they are real changes!) - We are now using other ESA based datasets such as GlobAlbedo but we don't know about the consistency of the land cover data with these data. Information on this would be helpful, also with other ESA based data. - Consistency is important, but for global simulations we need land cover change.
Spatial detail (300x300m)	- This is sufficient for climate applications (however, for land use change, I acknowledge that there may be a need to map at higher spatial resolutions) - Higher spatial detail might be quite useful for model development and subgrid parametrization of unresolved processes. -
Temporal resolution (5 yearly)	- It needs to be annual for use in transient land use change experiments. If it is not, then climate scientists will interpolate between the years. - Still ok. Consistency preferred to noise from annual time series. - Annual time series of LC change would be important for C cycle modeling and will have to be made for the next CMIP6 exercise.
Temporal extent (2000-2010)	- Again, a long time series will provide a big leap forward. - More than 30 years or at least 20, will be better. - Long time series of LC change would be beneficial
Land cover categories	- Inclusion of C3 and C4 grassland from a combination of agricultural statistics and temperature thresholds. - It will be useful to have distinction of managed grass divided into pasture and crops, as well as classification of raingreen shrubs. In addition, specific wetland types (also as a condition) would be helpful. For example, merged with the surface water bodies so that lakes and wetlands may be separated. We need to further discuss and think how best to link LC classes to PFTs - More accurate description of Shrub and moss/lichen areas would be desired for high latitude regions in Siberia (this has been discussed with UCL who are trying to implement something in later versions, although we recognize this is difficult).
Type of land cover change	- Changes in fractional cover of classes on a gradient. Change between bare – grass, grass – shrub, shrub – tree and tree – grass would be nice - - All transitions LC classes that are possible. Typical LC changes (btw forest, grass, crop) but possibly also between primary forest and secondary forest if possible or Grazed versus natural grassland.

2.7 Aspects of the CCI-LC maps to be improved

Dimension	Improvements (in your opinion)
Quality flags, metadata and format	- Some hints how to interpret quality flags will be useful. There is a lot of space to improve metadata information by adding netcdf attributes following CF convention. Netcdf format with the conventions for CF (Climate and Forecast) metadata (http://cfconventions.org/) is preferred since it is predominantly used in climate community. - Netcdf is sufficient. We need to understand more how to use the quality flags before saying if they are improved. Metadata is mostly sufficient, but it would be better if changes in the maps could be communicated more thoroughly with climate users.

2.8 Order of priority between main IPCC land categories classes for LC change between epochs

	Priority					
IPCC land category	**1**	**2**	**3**	**4**	**5**	**6**
Forest	MOHC-MPI-LSCE					
Agriculture	MPI	MOHC-LSCE				
Grassland	MPI	MOHC	LSCE			
Settlement			MPI	LSCE	MOHC	
Wetland		MPI				MOHC-LSCE
Other land			MOHC-MPI		LSCE	

2.9 Order of priority new attributes to be included in the future for modelling applications

	Priority						
LC attributes	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Vegetation height	MOHC		MPI - LSCE				
Minimum and maximum Leaf Area Index (LAI)	MPI		MOHC		LSCE		
Clumping index				LSCE	MPI		MOHC
Distinction between C3 and C4 plants	LSCE	MOHC		MPI			
Aboveground biomass		MPI-LSCE		MOHC			
Vegetation density						MOHC-LSCE	MPI
Land Management		LSCE			MOHC	MPI	

2.10 Expectations for the new Land Cover Maps - Phase 2 (2014-2016)?

Upcoming Land Cover Maps	Expectations
Global land cover map for the 1980s	- Annually changing LC map for each year, with documentation about limitations - Consistency with 1990s maps and classifications. No artificial jumps between the epochs for LC fractions at coarser resolutions, e.g. 0.5 degree. Important for investigating LC change over several decades. - Annual LC change where possible
Global land cover map for the 1990s	- Annually changing LC map for each year, with documentation about limitations - Consistency with 2000s maps and classifications. No artificial jumps between the epochs for LC fractions at coarser resolutions, e.g. 0.5 degree. Important for investigating LC change over several decades. - Annual LC change where possible

2.11 Opinion towards upcoming aspects of HR LC map

What are your expectations regarding the concept of hierarchical legend?

- ….
- Does the HR resolution lead to improvements in LC fractions on coarser scales, e.g. 0.5 degree? HR resolution might open new opportunities for research on the effect of land surface heterogeneity, i.e. how important it is to know where clusters of a certain LC type are located within a gridbox compared to considering a fraction without location information.
- I am not sure we have a strong opinion on this at this time. For us what is important is the density of vegetation for woody savannas, to distinguish between agriculture and grasses and for each between C3 and C4, and to distinguish between evergreen and deciduous tropical forest.

What would be the 5 level 1 and level 2 classes of interest?

<table>
<tr><th colspan="2">MOHC</th><th colspan="2">MPI</th><th colspan="2">LSCE</th></tr>
<tr><th>Level 1 classes</th><th>Level 2 classes (max 10 classes)</th><th>Level 1 classes</th><th>Level 2 classes (max 10 classes)</th><th>Level 1 classes</th><th>Level 2 classes (max 10 classes)</th></tr>
<tr><td>1. Tree cover</td><td>Broadleaf Evergreen (Closed)
Broadleaf Deciduous (Closed)
Broadleaf Evergreen (Open)
Broadleaf Deciduous (Open)</td><td colspan="2" rowspan="3">We don't understand this question. Major classes are more important than minor classes but in the end we need to do a conversion to PFT anyway. In principle more classes may be better to allow for a finer separation into Model PFTs</td><td>1. Agriculture</td><td>C3
C4</td></tr>
<tr><td>2. Shrub cover</td><td>Broadleaf Evergreen (Closed)
Broadleaf Deciduous (Closed)
Broadleaf Evergreen (Open)
Broadleaf Deciduous (Open)</td><td>2. Grass</td><td>C3
C4</td></tr>
<tr><td>3. Grass cover</td><td>Natural C3
Natural C4
Managed C3
Managed C4
Cropland C3
Cropland C4</td><td>3. Open canopies</td><td>Mix of vegetation types for woody savannas (mosaic classes?)</td></tr>
</table>

4. Non-vegetated	Urban Bare soil Water Snow		**4.Evergreen closed forest**	
5.			**5. Deciduous closed forest**	Different levels of deciduousness

Establish priorities for the area of change and LC classes of interest for the evaluation of change trajectories

- Over what time scale does this mean? Seasonal cycle? Or actual changes in LC state? All changes between level 1 classes would be top priority.
- Forest – Crops –grassland – bare soil
- Mostly deforestation, so transitions from forest to non-forest

3 ESA-CCI Land Surface Seasonality products

3.1 How do you use or have used the seasonality products in your modelling application?

	As a proxy for land surface parameters	Proxy for human activities	Validation of model outputs	Other (please indicate)
Vegetation greenness	MPI		LSCE	
Snow occurrence				
Burned areas occurrence				

3.2 Problems when using the seasonality products

	Vegetation greenness	Snow occurrence	Burned areas occurrence
MOHC			
MPI	The period of availability of one year (1999) is something we can work with, but it will be better to have a longer period. The same applies for other seasonality products.		
LSCE	No problem reported		

3.3 Consistency of the Land Surface Seasonality products with others CCI-LC products

	I did not check consistency with this product	Rather insufficient	With some problems	Sufficient

Consistency among seasonality products	MPI-LSCE
Consistency with global land cover maps	MPI-LSCE
Consistency with MERIS surface reflectance time series	MPI-LSCE
Consistency with the global water bodies product	MPI-LSCE

3.4 Did you use quality flags?

		Reasons
Yes	0%	-
No	MPI-LSCE (100%)	- Not sure how to interpret them - As for the LC maps we need to be more aware of how to use the quality flags correctly

3.5 Key aspects for future improvements

	MOHC	MPI	LSCE
Vegetation greenness		Extension of the period, monthly means	A full time series would be better suited to the application. However I could derive this from the surface reflectance product.
Snow occurrence		Extension of the period, monthly means	Separation of snow occurrence with respect to vegetation cover type : big trees versus Grass/shrub
Burned areas occurrence		Extension of the period, monthly means	Coherence between burned areas and a yearly land cover map product would be good

3.6 Prototype seasonality product about evapotranspiration. Did you test it?

Yes	MPI-LSCE (66%)
No	MOHC (33%)

3.7 If you tested the Evapotranspiration product, could you summarize your experience? If not, explain the reason.

	Experience/ Reason
MOHC	I haven't used it yet, but I will by the meeting (end July). I plan to use it evaluate against another ET product (Jung ET dataset), and use both datasets to evaluate JULES simulations over Africa.

MPI	Comparison of JSBACH evapotranspiration with ESA-CCI-ET product reveals that our model overestimate ET in extra-tropics, and underestimate tropical evapotranspiration, especially in Amazon river basin. Globally model underestimate ET, however both datasets (model and observation) show agreement in increase of ET for 2010 in comparison with July 2009. Some problems were detected in ET product during winter, probably due to limitations of the data acquisition during the winter.
LSCE	We evaluated the ET against the JUNG ET product and the ORCHIDEE simulations in a preliminary investigation. In general the values ET product is significantly lower than the ORCHIDEE simulations globally, and somewhat lower than the JUNG ET product except for many semi-arid regions (Sahel, Arabian Peninsula, Australia). We need to do a further analysis, but for the moment we are unclear as to why there are differences between the ET products.

3.8 Order of priority additional seasonal (or LC condition) products

	Priority		
Seasonal products	**1**	**2**	**3**
FaPAR		MOHC-LSCE (66%)	MPI (33%)
Permafrost fraction		MPI (33%)	MOHC-LSCE (66%)
Vegetation and soil surface albedo	MOHC-MPI-LSCE (100%)		

3.9 Land Surface Seasonality products relevant for current and future modelling application

	Current modelling application	**Future modelling application**
MOHC	LAI: Currently, we use a 5 year MODIS LAI climatology for each PFT as a model prognostic (meaning it is used when running the model). We would like to update this so that we use satellite data that is consistent with LC_CCI (SPOT VGT, MERIS and PROBA-V), and has some objective way of splitting observed LAI to different functional types.	LAI: If we were to have LAI on different PFTs as a climatology, we could also use this for model evaluation and improvements to the phenology scheme.
MPI	Seasonal extension of irrigation and wetlands, seasonal extend of vegetation Desired temporal resolution is monthly.	Seasonal extension of irrigation and wetlands, seasonal extend of vegetation Desired temporal resolution is monthly.
LSCE	LAI Wetland dynamics LST Soil moisture	Forest canopy gaps (indication of forest density)

4 ESA-CCI Meris Surface Reflectance

4.1 Did you use Meris Surface Reflectance in your modelling application?

Yes (0%)

No MOHC-MPI-LSCE (100%)

4.2 How did you use it?

	As a proxy for land surface parameters	Proxy for human activities	Validation of model outputs	Other (please indicate)
Meris Surface Reflectance				

4.3 Problems when using Meris Surface Reflectance

MOHC ------

MPI ------

LSCE ------

4.4 Did you use quality flags? Reasons

Yes ------

No ------

4.5 Consistency of Meris Surface Reflectance with others CCI-LC products

	I did not check consistency with this product	Rather insufficient	With some problems	Sufficient
Consistency with seasonality products	MPI			
Consistency with global land cover maps	MPI			
Consistency with the global water bodies product	MPI			

4.6 In the future, do you plan to use the ESA-CCI Meris Surface Reflectance for your modelling application?

Yes MPI-LSCE (66%)

No MOHC (33%)

4.7 Key aspects for future improvements of the ESA-CCI Meris Surface Reflectance for your modelling application

MOHC ------

MPI First we need to check the usability to represent land surface parameters and/or its proxies, e.g. for the fraction of vegetation or albedo.

LSCE I may use it to derive a time series of NDVI for model evaluation (Note that so far MODIS products were more easy to access and use)

5 ESA-CCI Water Bodies

5.1 How do you use or have used Water Bodies in your modelling application?

	As a proxy for land surface parameters	Proxy for human activities	Validation of model outputs	Other (please indicate)

Water Bodies	MOHC-MPI		MPI-LSCE	MOHC: as a comparison with other global land cover maps. LSCE: To prescribe water bodies: again have not yet used the product in this way

5.2 Problems when using Water Bodies

MOHC	**Purpose 1: As a proxy for land surface parameters.** We found that the WB extent in LC_CCI is the maximum water extent over the whole year (and most likely full time series). It would be nice to have a seasonal or monthly climatology of water extent, since it can have quite a large impact on seasonal dust aerosols in arid and semi-arid areas. **Purpose 2: As a comparison with other global land cover maps.** Water class did not separate inland water from marine water. This meant I had to delineate it for myself, using a technique that involved flood filling from seed points in the ocean. I had to manually digitize barriers on the coastline to identify the boundary between inland water and marine water. The Met Office unified model needs this because we have an ocean model for the marine part, and the land surface model (JULES) simulates interactions between surface water on the land and the atmosphere.
MPI	**Purpose 1: As a proxy for land surface parameters.** Artificial water bodies along the coastlines due to aggregation. **Purpose 2: Validation of model outputs.** In general there is not clear definition and distinction between wetlands and water bodies, so it is hard to compare it with other datasets
LSCE	Not answered**.**

5.3 Did you use the extra NObsImsWS and NObsImsGM bands?

	Yes	No	Reasons:
NObsImsWS		MOHC-MPI	MOHC: Didn't have time to look at this MPI: I was not sure how to interpret these data. LSCE: Not answered
NObsImsGM		MOHC-MPI	MOHC: Didn't have time to look at this MPI: Not answered LSCE: Not answered

5.4 Consistency of Water Bodies with others CCI-LC products

	I did not check consistency with this product	Rather insufficient	With some problems	Sufficient
Consistency with seasonality products	MOHC-MPI			

Consistency with global land cover maps	MPI
Consistency with MERIS surface reflectance time series	MOHC-MPI

5.5 Key aspect for future improvements of Water Bodies for your modelling application

	Water bodies dynamics	More detailed typology (e.g. lakes, river, ocean)	Higher spatial resolution	Other (please indicate)
Water Bodies	MOHC-MPI	MOHC-MPI		

Specific aspects for future improvements:

MOHC	See descriptions of purpose 1 & 2. In summary, would be nice to see: - Seasonal or monthly average dynamics of water body extent - Separation between marine and inland water
MPI	See above

6 User Tool

6.1 Did you use the reprojection and class aggregation tool of the ESA-CCI land cover data?

		Version	Products
Yes	MOHC-MPI-LSCE (100%)	MOHC: v3.6, v3.7 and v3.9 MPI: v3.0, v3.3, v3.7, v3.9 LSCE: v3.1, v3.7 and v3.9	MOHC: mostly on 2010 LC, but also on 2000 and 2005 LC MPI: LC maps, NDVI LSCE: maps and NDVI condition
No	0%		

If no, explain the reason:

- MPI: For evapotranspiration there is no guidance in documentation if the tool can aggregate it at all, so I have to develop my own tool based on gdal, cdo and nco libraries. Perhaps, this might be the hint how to improve the lc-user-tool on basis of using gdal, cdo and nco libraries. Tools (code) written in java or javascripts are not that common in climate modeling community.

6.2 Was the reprojection and class aggregation tool useful?

Yes MOHC-MPI-LSCE (100%)

No 0%

6.3 Did you use the LC class – PFTs convertion tool?

Yes MOHC-MPI-LSCE (100%)

No 0%

If yes, did you use:

The default cross-walking table	MOHC-MPI-LSCE (100%)
A user-defined cross walking table	MOHC-LSCE (66%)

6.4 Functionalities of the user tool

	I did not check this function	Rather insufficient	With some problems	Sufficient
Ranking of LC class by fractional area in target cell	MOHC			MPI-LSCE
Fractional area of each LC class				MOHC-MPI-LSCE
Fractional area of each PFT				MOHC-MPI-LSCE
Reprojection			MPI	MOHC-LSCE

6.5 Key aspect for future improvements of the user tool for your modelling application

	Distinction between C3/C4 plants	Biomes delineation	Other (please indicate)
User Tool	MOHC-MPI-LSCE	MOHC-MPI-LSCE	MPI: Classification of managed grass (crops and pasture), and introduction of raingreen shrubs. LSCE: Possibility to use different cross-walking tables for different regions

Specific aspects for future improvements:

MOHC	I would also like to see the user tool be able to: - Read the class numbers at the start of rows, or PFT names at the top of columns. Currently it seems to assume the position in the table relates to a certain landcover class. This is misleading, and has lead to confusion and errors in the output. - Aggregate to a rectangular grid. Almost all climate models use a rectangular grid, so direct aggregation to that should be another priority. Currently, I have been using the aggregation tool to aggregate to 0.125 degrees, then regridding to a rectangular grid. Clearly, this can lead to errors, so it would be nice to be able to do it directly.
MPI	Biomes delineation: a separation, e.g., of tropical and extra-tropical classes would be very helpful. Diversification of managed grass into pasture and crops New phenotype for shrubs: raingreen

LSCE	To make the tool as generic as possible, LSCE project members have thought of an approach where any number of user-defined global maps are fed into the tool. These maps would contain regions with particular feature the user wants to use in the classification (be it C3/C4 or biomes or anything else). A conversion table would then also be read by the tool, that would define a) how to map from the LC classes to "phenological types" as is done currently (e.g. tree broadleaved evergreen) but b) would also detail how to use the classes derived in the user-input global maps to convert between LC classes and more specific categories. This approach has been discussed in an informal manner during project meetings with project partners at Brockmann Consulting and other climate users. We would welcome the chance to discuss this further if this is a direction the project partners want to follow.

7 Communication between ESA-CCI land cover producers and users

7.1 Communication between data producers and users

Sufficient	0%
With some problems	MOHC-MPI-LSCE (100%)
Rather insufficient	0%
There was no communication	0%

7.2 How could the communication be improved?

MOHC	MPI	LSCE
Generally, the communication is excellent, but on some occasions we have been waiting a long time for data to arrive, without an explanation of why it is delayed.	I (Goran) would appreciate an info mail when new product or new version or revision of the data or lc-user-tool is released. This is very critical issue, since even the small changes in the input data can make our analysis unreliable i.e. not comparable if we cannot track the changes. On several occasions I haven't got very important emails because I was not on a mailing list of sender (for example email in which this survey was attached has been forwarded to me by Stefan, and be-fore the meeting in Frascati, I never got the agenda for that meeting). So, maybe I miss some other mails too.	All changes that are made to the maps and tool between different versions could be summarized in a document and sent to all climate users. We feel there has been a miscommunication throughout phase 1 with the issue of land cover change detection. This has been ex-pressed by LSCE and noted by the UCL project partners and will be discussed further at the next project meeting. We would like to sug-gest that in the future key points on how the maps should be used should be highlighted to the users. Perhaps we could have 2-slide summary of "highlights for climate users" at each meeting. And/or that this information could get sent to climate users periodically.

7.3 ESA-CCI land cover products reports used in your modelling application

Abrev	Report	Used by	7.4 How do you judge it? Not Useful	Useful	Very Useful
ATBD	Algorithm theoretical basis document	MOHC-LSCE (66%)		MOHC-MPI-LSCE	
CAR	Climate assessment report	MOHC-MPI-LSCE (100%)		MOHC	MPI
DARD	Data access requirements document	0%		MPI	

DPM	Detailed processing model	0%	MPI	
IODD	Input output data description	LSCE (33%)	MPI-LSCE	
IPVR	Internal preliminary validation report	MOHC-MPI-LSCE (100%)	MOHC-MPI-LSCE	
PSD	Product specification document	MPI-LSCE (66%)	MPI-LSCE	
PVIR	Product validation and Inter-comparison report	MPI (33%)	MPI	
PVP	Product validation plan	LSCE (33%)	MPI-LSCE	
SPD	System prototype description	0%	MPI	
SRD	System requirements document	0%	MPI	
SSD	System specification document	0%	MPI	
SVR	System verification report	0%	MPI	
URD	User requirements document	MPI-LSCE (66%)	LSCE	MPI

7.5 How could the reporting be improved?

MOHC Not sure where it is in the above, but a bit more detail on the aggregation tool would be nice. For example, I only discovered by trial and error that it didn't actually read the land cover class number from the cross walking table.

MPI At first just a brief comment that all the reports are more or less equally useful. I just put CAR as very useful, since when I joined the project I spent most of the time reading CAR to see what has been done so far and what we have to do in the next phase. Therefore, I indicated CAR as very useful. URD also got very useful mark, since it represents communication between climate modeling users and data producers. Other reports contain information that are in general useful for climate users, but it is not likely that he or she will use them on daily basis. In general I think they are too long, but report has to be as long as needed to contain all the necessary information. Some reports contain summaries some other purpose and scope, but in both cases this chapters coming after long list of administrative pages such as list of recorded changes, list of references, list of symbols and abbreviations. I would like to suggest to put summary just after the title, and then all the lists. I think this will improve readability and possibility to quickly find the document that you are looking for

LSCE The user document could also contain the "key messages for users" in order to highlight the main points/caveats in using the products.

8 Final remarks

8.1 Final remarks

MOHC I see the key challenges for the remainder of the project are as follows (all are discussed above, and approximately in order):

1. Extend the time series so that we can use it for modelling experiments in year 3, including (in order of priority):
   a. Annual land cover
   b. 1990s
   c. 1980s
   d. 2015
2. Implement more LC changes (ie. Not just forest related change)
3. Further improvements to the user tool and its documentation
4. C3 and C4 mapping
5. Water bodies:
   a. seasonality product
   b. inland water / marine water distinction
6. Canopy height description / map related to LC
7. LAI per PFT

MPI For our model application it will be very useful to have separated albedo into soil and vegetation fraction. For that purpose ideal would be to have time series of monthly vegetation fractions and global albedo (visible and near infrared band). Alternatively instead of monthly vegetation fraction, fapar might be used or perhaps NDVI as a proxy, assuming that these datasets would be consistent with GlobAlbedo. Therefore, products (such as: fraction of green vegetation, fapar, NDVI, LAI, snow cover), with monthly resolution for longer time period are desired. Another condition for this data is to be consistent with ESA Globalabedo.
Dynamical water body with typological distinction of water body types (lake, wetland, irrigated area, etc…), with monthly resolution for at least 5 years, but longer period (20 or 30 years) is always better in climate application.

LSCE No remarks