Climate Change Initiative Extension (CCI+) Phase 1 New Essential Climate Variables (NEW ECVS) High Resolution Land Cover ECV (HR\_LandCover\_cci)

# Product Validation and Intercomparison Report

# (PVIR)

Part A – Intercomparison Report

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# Changelog

Issue	Changes	Date
1.0	First version.	17/07/2020
1.1	Second version with the results of the visual qualitative assessment of the RR prototypes	18/08/2020
1.2	Third version including a section on the quantitative assessment of the RR prototypes for Africa and a section about the qualitative assessment of Amazon and Siberia. It also includes results of inter-comparison with existing land cover for all RR prototypes and static maps in Siberia and Amazon.	18/11/2020
1.3	Updated version according to CCI_HRLC_Ph1_AR2_RID-ESA.xlsx Sections 4.2.2 and 4.2.3 updated to include results of inter-comparison with Atlas of Urban Expansion as suggested during AR2.	07/12/2020
1.4	Updated with the quantitative assessment of the RR prototypes for Amazonia and Siberia, update of the quantitative assessment of the RR prototype for Africa. Also includes qualitative assessment of the African zoom area and Amazonian historical maps. Regarding inter-comparison with existing the results of land cover data in Amazon zoom area are added (Section 3.3)	04/02/2021
2.0	Executive summary updated with dates of the second production product delivery. Updated section 2 with current current area locations. The introductory part of Section 3 was expanded to explain how the results are interpreted. When the first production is concerned section 3.2.3 is updated with benchmarking results of Africa product for static region, and Section 4.3 with benchmarking results of products for Siberia (3.3.7 -3.3.12) and Africa (3.3.13 - 3.3.18) historical regions. Benchmarking results of the second production related to static maps are added in Section 3.5, and those related to the historic maps in Section 3.6. Moreover, Section 3.4 related to the estimation of the reliability of the existing data was added too. In this issue the intercomparison analysis (PVIR-Part A) has been separated from the validation one (PIVIR-Part B). This document refers to intercomparison analysis (PVIR-Part A), only.	28/10/2022
2.1	Correction of Table 65 and related parts in 3.5.2.1.	01/02/2023

# Detailed Change Record

Issue	RID	Description of discrepancy	Sections	Change
1.3	FR-01	It does not match with the document version. It should be 'CCI_HRLC_Ph1- PVIR_1.2' instead of 'CCI_HRLC_Ph1- PVIR_2.1'.		Filename of version v1.2 is fixed.
	FR-02	In the table reporting the new legend is not present the 'No Data' class (0 value).	Section 2	Updated Table 1.

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# **1** Introduction

## **1.1 Executive summary**

The Product Validation and Intercomparison Report (PVIR) is a living document that describes and presents all activities aimed at evaluating the quality of the various CCI HRLC products and at comparing them to existing LC maps.

The quality assessments included in the present document are first made on **RR prototypes** whose areas correspond to one S2 tile for Africa (T37PCP), two for Amazonia (21KUQ and 21KXT) and one for Siberia (42WXS). A first delivery was done in July 2020 but the SAR S1 prototypes for Siberia and Amazonia had smaller area than other prototypes. Therefore, these prototypes were updated 02/10/2020 and 09/10/2020 respectively. While fusion products were updated on 10/10/2020 for MRF algorithm, and 15/10/2020 for LOGP algorithm. Some of the analyses were already done by the time the problem with SAR S1 size was noticed and were not repeated. The quality of all RR prototypes have been evaluated qualitatively and the Africa RR prototypes were quantitatively assessed.

Second, **static land cover maps over a "zoom area"** were made available on 21/10/2020 for Amazonia and Siberia. The PVIR includes their qualitative assessment and reports about the improvements brought from the RR stage to these LC maps classified at a larger extent.

Inter-comparison was done for all the products available at the time of the document conclusion. However, problem of SAR S1 size affected the RR products inter-comparison in case of 21KUQ and 21KXT tiles. Additional details are provided in Section 4.1.

Regarding the second production, the products were delivered on the following dates. The static map for Siberia was provided initially on 04/02/2022, but the reprocessed and final version was provided on 24/06/2022. The static map in Amazon was provided on 15/04/2022. The static map for Africa was provided on 18/07/2022. The first versions of historical maps for Siberia were provided on 12/08/2022, while the second and final versions of products for Siberia were provided on 22/08/2022. Historical products for Amazon were provided on 01/09/2022, and for Africa on 06/10/2022. This report refers to the final versions of products.

This document (PIVIR-Part A) only includes intercomparison analysis. For validation analysis refer to PIVIR – Part B.

## **1.2** Purpose and scope

The Product Validation and Intercomparison Report Part A and B give a complete report of the activities executed to assess the quality of the following CCI HR Land Cover products:

- HRLC prototypes on limited spatial extents dedicated to a Round Robin (RR) assessment.
- An HRLC map at the zoom level at a spatial resolution 10m that is a precursor to the HRLC maps at the subcontinental level.
- An HRLC map at the subcontinental level at a spatial resolution of 10m as reference static input to the climate models.
- A long-term record of regional HRLC maps at a spatial resolution of 30m in sub-regions of the static input for historical analysis every 5 years.
- The change information at 30 m and yearly scale for HRLC map update.

#### **1.3 Applicable documents**

#### Ref. Title, Issue/Rev, Date, ID

- [AD1] CCI HR Technical Proposal, v1.1, 16/03/2018
- [AD2] CCI Extension (CCI+) Phase 1 New ECVs Statement of Work, v1.3, 22/08/2017, ESA-CCI-PRGM-EOPS-SW-17-0032
- [AD3] Data Standards Requirements for CCI Data Producers, v2.0, 17/09/2018, CCI-PRGM-EOPS-TN-13-0009
- [AD4] CCI\_HRLC\_Ph1-D1.1\_URD, the latest version
- [AD5] CCI Extension (CCI+) Phase 1 Product User Guide (PUG) v2.0.3, 29/10/2022, ESA-CCI-HRLC
- [AD6] CCI\_HRLC\_Ph1-D2.5\_PVP, the latest version

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### **1.4 Reference documents**

#### Ref. Title, Issue/Rev, Date, ID

- [RD1] The Global Climate Observing System: Implementation Needs, 01/10/2016, GCOS-200
- [RD2] Bartsch, Annett; Widhalm, Barbara; Pointner, Georg; Ermokhina, Ksenia; Leibman, Marina; Heim, Birgit (2019): Landcover derived from Sentinel-1 and Sentinel-2 satellite data (2015-2018) for subarctic and arctic environments. Zentralanstalt für Meteorologie und Geodynamik, Wien, PANGAEA, <u>https://doi.org/10.1594/PANGAEA.897916</u>

#### 1.5 Acronyms and abbreviations

AUE	Atlas of Urban Expansion
CCI	Climate Change Initiative
ESA	European space agency
FAO	Food and Agriculture Organization
FCMU – SBB	Forest Cover Monitoring Unit Foundation for Forest Management and Production Control
FNF	Forest / Non-Forest map
FROM-GLC	Finer Resolution Observation and Monitoring of Global Land Cover
GHS BU	Both GHS BU LDS and GHS BU S1
GHS BU LDS	Global Human Settlement Built-Up Grid – Landsat
GHS BU S1	Global Human Settlement Built-Up Grid – Sentinel-1
GL30	GlobeLand30
GSW	Global Surface Water
GUF	Global Urban Footprint
HR	High resolution
INPE	Brazilian National Institute for Space Research
LC	Land cover
LCC	Land cover change
LCCS	Land cover classification system
LOGP	Logarithmic opinion pool decision fusion
LSTM	Long Short-Term Memory
LSTM – MC	LSTM Monthly Composite
LSTM – TS	LSTM Time Series
MRF	Markov Random Field decision fusion
OA	Overall accuracy
PA	Producer's accuracy
PAb	Benchmark producer's accuracy
PVIR	Product Validation and Intercomparison Report
PVP	Product Validation Plan
RF	Random Forest classification algorithm
RR	Round Robin
SVM	Support Vector Machine classification algorithm
UA	User's accuracy
UAb	Benchmark user's accuracy
WSF	World Settlement Footprint

# 2 Overview of the CCI HR LC products

### 2.1 Overview

In the second and final production three types of land cover products were generated and validated thematically within the ESA CCI HRLC project:

- 10-m static sub-continental LC maps for the year 2019.
- 30-m regional historical (1990-2019) LC maps, generated every five years, since 1990 on reduced areas.

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- 30-m land cover change detected on an annual basis on Landsat time series. It was used to backdate, on a 5-year basis back to 1990, the detailed spatio-temporal 10-m static LC map.

In the first production, there was a fourth product, 10-m Round Robin local LC prototypes for the year 2019, produced through a Round Robin (RR) exercise during which optical and SAR classifications. This product was benchmarked with the aim of selecting the best algorithm, therefore it was not included in the second production. In the first production, the historical maps for 2019 were not included.

All three types of land cover products were generated over three areas selected through key users' consultation and internal consultation regarding feasibility and needs (Figure 1). The RR sites, in gray, covered 4 Sentinel-2 (S2) tiles located in the Amazonian region (21KUQ, 21KXT), in Siberia (42WXS), and in Africa (T37PCP). The static LC maps, in green, cover the regions of Amazon, Sahel and Siberia. The historical LC maps are restricted to the orange areas. The geographical coordinates of the three regions are the following:

#### Amazonia:

- Static map: (23.6°S 0°S; 42.9°W 62.1°W)
- Historical LC and LCC map: (23.6°S 11.7°S; 46.7°W 62.1°W)

#### Sahel:

- Static map: (0.1°S 18.1°N; 9.9°E 43.3°E),
- Historical LC and LCC map: (3.5°N 16.3°N; 27.0°E 43.3°E)

#### Siberia:

- Static map: (51.3°N 75.7°N; 64.4°E 93.4°E),
- Historical LC and LCC map: (59.4°N 73.9°N; 64.8°E 87.4°E).



Figure 1. Final localisation of the 3 study areas for the static and historical map [AD5].

### 2.2 Legend

Table 1 details the levels of the land cover legend associated with the CCI HRLC products. This legend is used both for the classification of the static map and for historical maps [AD5].



#### Table 1. Legend for the CCI HRLC [AD5]

	HRLC CL/	ASSES	
CODE	DESCRIPTION		
0	No data		
10	Tree cover evergreen broadleaf		
20	Tree cover evergreen needleleaf		
30	Tree cover deciduous broadleaf		
40	Tree cover deciduous needleleaf	F	
50	Shrub cover evergreen		
60	Shrub cover deciduous		
70	Grasslands		
80	Croplands		
90	Woody vegetation aquatic or reg	gularly fl	ooded
100	Grassland vegetation aquatic or	regularl	y flooded
110	Lichens and mosses		V
120	Bare areas		
130	Built-up		
140	Open water 1	141	Open water seasonal
	1	142	Open water permanent
150	Permanent snow and/or ice		

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# 3 Benchmarking with other existing products

For benchmarking, Overall accuracy (OA), Producer's accuracy (PA) and User's accuracy (UA) are computed for each RR product and static product using the existing land cover maps as a reference. Although the names of the indicators are referring to the accuracy, in case of inter-comparison they are expressing agreement between the products that are supposed to have the same accuracy/level of details. The computation is the same as for OA, PA and UA, however the existing land cover maps cannot be considered as actual reference data set and therefore they will be denoted with "b" in the subscript to refer to benchmark accuracy. The results will be shown in the separate subsections depending on if the metrics are for overall assessment or class specific. Individual accuracy indexes the classification are interpreted as "Excellent" if both scores PA<sub>b</sub> and UA<sub>b</sub> are above 90% % for most of the compared datasets, "Well" if the scores are between 70% and 90%, and "Relatively good" if the scores are between 50% and 70%. The classes for which individual accuracy indexes are less than 50% for most of the compared datasets are not considered in the conclusions.

# 3.1 RR prototypes

At the moment of inter-comparison, the delivered prototypes from the SAR chain had a defect in terms of tile size for 21KXT and 21QUQ regions – they were smaller than the prototypes from optical chain. The black area in Figure 2 represents the area that is missing – 47% in 21KXT and 38% in 21KUQ tiles - in case of RF (S1) algorithm. The discrepancy in size between SAR and optical prototypes is present also in Africa, but it is negligible. Since size discrepancy also affects fusion prototypes, correcting the defect and recomputing results would take significant amount of time, so it is omitted.

The size defect affects the possibility of comparison of prototypes from SAR processing chain (RF(S1)) results and results from the optical chain (SVM (S2)), LSTM – TS (S2), and LSTM - MC (S2)) for 21KXT and 21KUQ regions.

Despite this issue, it is possible to compare results between different prototypes derived from optical chain as well as the two fusion types. In regions 37PCP and 42WXS there are no constraints for comparison, since in these regions the size if correct.







#### Figure 2. RF (S1) size defect illustration

#### 3.1.1 Overall benchmark accuracy of RR products

RR products  $OA_b$  results are shown in the two tables, one classification outputs (Table 2) and one for fusion outputs (Table 3).

In Table 2 coloured values represent the highest scores among different algorithms. In case of 21KXT and 21KUQ only optical algorithms – SVM, LSTM-TS and LSTM – MC - were compared and the highest score is highlighted

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with red colour. For 37PCP and 42WXS all algorithms, including RF (S1), were compared and the highest one is emphasised in green.

Table 2. Over	all accuracy	for SAR a	and optical	processing	chain RR	prototypes
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RR tile	Algorithm	FNF	FROM- GLC	GHS BU S1	GL30	GSW season ality	GSW_ v1_2	MapBi omas	ESA DUE GlobP ermafr ost
	RF (S1)	69%	51%	100%	50%	100%	100%		
DO D	SVM (S2)	55%	51%	100%	54%	99%	99%		
21K	LSTM - TS (S2)	61%	47%	99%	51%	98%	98%		
	LSTM - MC (S2)	58%	47%	100%	53%	98%	98%		
	RF (S1)	77%	50%	98%	23%	99%	99%	49%	
ХT	SVM (S2)	84%	52%	100%	36%	100%	99%	52%	
21	LSTM - TS (S2)	83%	44%	99%	32%	99%	99%	43%	
	LSTM - MC (S2)	84%	48%	99%	34%	99%	99%	47%	
	RF (S1)	89%	54%	88%	56%	99%	99%		
Ð	SVM (S2)	93%	60%	98%	58%	99%	99%		
37F	LSTM - TS (S2)	91%	55%	96%	51%	98%	98%		
	LSTM - MC (S2)	92%	58%	97%	53%	98%	98%		
(S	RF (S1)	80%	41%	100%	38%	95%	94%		28%
N N	SVM (S2)	75%	35%	100%	36%	93%	93%		35%
42	LSTM - TS (S2)	77%	37%	100%	36%	95%	95%		40%

In Table 3 better performance of different fusion algorithms is highlighted in orange colour.

RR tile	Algori thm	FNF	FRO M- GLC	GHS BU S1	GL30	GSW seasona lity	GSW_ v1_2	MapBiom as	ESA DUE Glob- Permafrost
21/10	LOGP	56%	53%	100%	54%	99%	99%		
ZIKUQ	MRF	56%	53%	100%	54%	99%	99%		
21///	LOGP	85%	55%	100%	36%	99%	99%	54%	
21671	MRF	85%	56%	100%	36%	100%	99%	55%	
27000	LOGP	92%	61%	97%	60%	99%	99%		
37PCP	MRF	93%	62%	98%	61%	99%	99%		
1314/145	LOGP	78%	38%	100%	39%	95%	94%		31%
427773	MRF	78%	35%	100%	40%	95%	94%		33%

 Table 3. Overall accuracy for fusion RR prototypes

 $OA_b$  results were used to calculate the yield from fusion. The fusion algorithm with better performance MRF was compared to RF and SVM algorithms since these are the two algorithms involved in the fusion. Comparison is done by mean of difference shown in the Table 4 where positive yield is highlighted in green and negative in red.

Table 4. Yield from fusion

RR tile	Comparis on	FNF	FROM GLC	GHS BU S1	GL30	GSW seasonality	GSW_ v1_2	MapBi omas	ESA DUE Glob- Permafrost
<b>37PCP</b>	MRF-RF	4%	8%	10%	5%	0%	0%	0%	0%

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	MRF-SVM	0%	2%	0%	3%	0%	0%	0%	0%
1214/145	MRF-RF	-2%	-6%	0%	2%	0%	0%	0%	5%
420085	MRF-SVM	3%	0%	0%	4%	2%	1%	0%	-2%

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#### 3.1.2 Per class benchmark accuracies - Producer's accuracy (PA<sub>b</sub>) and User's accuracy (UA<sub>b</sub>) - RR products

In this section results of UA<sub>b</sub> and PA<sub>b</sub> for RR products are presented. The results are organized in the tables where each table consists of results for two types of algorithms for producing RR products for single RR region as follows:

- Table 5. UA<sub>b</sub> and PA<sub>b</sub> for Amazon 21KUQ RF (S1) and SVM (S2) algorithms
- Table 6. UA<sub>b</sub> and PA<sub>b</sub> for Amazon 21KUQ LOGP and MRF decision fusion algorithms
- Table 7. UAb and PAb for Amazon 21KUQ LSTM TS (S2) and LSTM MC (S2) algorithms
- Table 8. UAb and PAb for Amazon 21KXT RF (S1) and SVM (S2)
- Table 9. UAb and PAb for Amazon 21KXT LOGP and MRF decision fusion algorithms
- Table 10. UAb and PAb for Amazon 21KXT LSTM TS (S2) and LSTM MC (S2) algorithms
- Table 11. UAb and PAb for Africa 37PCP RF (S1) and SVM (S2) algorithms

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- Table 12. UA<sub>b</sub> and PA<sub>b</sub> Africa 37PCP LOGP and MRF decision fusion algorithms
- Table 13. UA<sub>b</sub> and PA<sub>b</sub> for Africa 37PCP LSTM TS (S2) and LSTM MC (S2) algorithms
- Table 14. UA  $_{b}$  and PA  $_{b}$  for Siberia 42WXS  $\,-$  RF (S1) and SVM (S2) algorithms part 1
- Table 15. UAb and PAb for Siberia 42WXS RF (S1) and SVM (S2) algorithms part 2
- Table 16. UA<sub>b</sub> and PA<sub>b</sub> for Siberia 42WXS LOGP and MRF decision fusion algorithms part 1
- Table 17. UAb and PAb for Siberia 42WXS LOGP and MRF decision fusion algorithms part 2
- Table 18. UA<sub>b</sub> and PA<sub>b</sub> for Siberia 42WXS LSTM TS

In these tables the UA<sub>b</sub> and PA<sub>b</sub> scores above 50% are highlighted in red as this amount of agreement with existing data can be considered more than random.

Furthermore, average of  $UA_b$  and  $PA_b$  was computed for summarizing numerous results and determining best performing algorithm. For comparison purposes average value for each of the indexes is separately shown for fusion algorithms and for classification algorithms as follows:

- Table 19. Average UA<sub>b</sub> per fusion algorithm and RR region
- Table 20. Average UA<sub>b</sub> per classification algorithm and RR region
- Table 21. Average PA<sub>b</sub> per fusion algorithm and RR region
- Table 22. Average PA<sub>b</sub> per classification algorithm and RR region
- Table 23. Mean and standard deviation of UA and PA of SVM algorithm

In Tables Table 19-Table 22 the highest score among algorithms is highlighted in yellow. Furthermore, last rows of the table highlighted in orange contain count of number of times when algorithm was better than the others.

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# 3.1.2.1 Table 5. UA<sub>b</sub> and PA<sub>b</sub> for Amazon 21KUQ – RF (S1) and SVM (S2) algorithms

Algorithm	Dataset	Index	Bareland	Built-up	Cropland	Forest	Grassland	Shrubland	Water	Water Permanent	Water Seasonal	Wetland
	GL20	PAb	55%	2%	21%	82%	20%	21%	22%			1%
	GLSU	UA <sub>b</sub>	0%	0%	74%	70%	23%	24%	37%			14%
		PAb	26%	4%	32%	92%	24%	15%	67%			4%
~	FROM-GLC	UAb	0%	0%	5%	66%	88%	13%	16%			14%
Û,	ENE	PAb				57%			1%			
21		UA <sub>b</sub>				46%			1%			
<b>S1</b> )	GSW	PAb								0%	7%	
RF (	seasonality	UA <sub>b</sub>								1%	19%	
	GSW v1 2	PAb								0%	8%	
	0300_01_2	UA <sub>b</sub>								0%	35%	
		PAb		0%								
	GH3 BO 31	UAb		0%								
	GI 30	PAb	64%	3%	30%	92%	20%	6%	53%			4%
	GESU	UA <sub>b</sub>	0%	9%	73%	64%	22%	20%	16%			17%
		PAb	54%	8%	42%	96%	24%	3%	88%			10%
đ		UAb	0%	5%	6%	57%	89%	7%	12%			9%
Ň.	ENE	PAb				95%			90%			
) 21		UAb				39%			10%			
(S2	GSW	PAb								74%	7%	
Σ	seasonality	UAb								10%	24%	
S	GSW/ v1 2	PAb								81%	8%	
	0300_01_2	UAb								10%	42%	
		PAb		10%								
		UAb		2%								

Cesa	Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>mage</b> high resolution
	Issue	Date	Page	and cover
	2.rev.1	01/02/2023	14	CCI

# 3.1.2.2 Table 6. UA<sub>b</sub> and PA<sub>b</sub> for Amazon 21KUQ – LOGP and MRF decision fusion algorithms

Algorithm	Dataset	Index	Bareland	Built-up	Cropland	Forest	Grassland	Shrubland	Water	Water Permanent	Water Seasonal	Wetland
	CI 20	$PA_b$	69%	3%	28%	92%	24%	7%	51%			4%
	GLSU	UAb	0%	13%	73%	65%	23%	22%	24%			25%
		$PA_b$	54%	7%	42%	96%	27%	4%	89%			9%
	PROM-GLC	$UA_b$	0%	7%	6%	57%	90%	8%	18%			13%
Sugar Sector	ENIE	PAb				95%			89%			
21 K	FINF	UAb				39%			15%			
GP 2	GSW seasonality	$PA_b$								73%	8%	
ŏ	USW Seasonality	UA <sub>b</sub>								16%	24%	
	GSW/y1 - 2	PAb								81%	8%	
	GSW_v1_2	UAb								15%	42%	
	GHS BU S1	$PA_{b}$		10%								
		UA <sub>b</sub>		3%								
	GL30 -	PAb	72%	2%	28%	92%	24%	7%	51%			4%
		UAb	0%	14%	73%	65%	23%	22%	25%			25%
	FROM-GLC	$PA_{b}$	53%	6%	43%	97%	27%	3%	89%			9%
		UA <sub>b</sub>	0%	8%	6%	57%	90%	8%	19%			13%
Ŋ	ENIE	PAb				95%			90%			
1 K		UAb				39%			16%			
R 2	GSW seasonality	PAb								74%	7%	
MR	GSW Seasonality	UA <sub>b</sub>								17%	23%	
	GSW/ v1 2	PAb								81%	8%	
	0311_01_2	UA <sub>b</sub>								16%	42%	
	GHS BU S1	$PA_b$		8%								
		$UA_b$		3%								

	Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>mage</b> high resolution
<b>esa</b>	Issue	Date	Page	and cover
	2.rev.1	01/02/2023	15	CCI

#### 3.1.2.3 Table 7. UA<sub>b</sub> and PA<sub>b</sub> for Amazon 21KUQ – LSTM - TS (S2) and LSTM - MC (S2) algorithms

Algorithm	Dataset	Index	Bareland	Built-up	Cropland	Forest	Grassland	Shrubland	Water	Water Permanent	Water Seasonal	Wetland
	CL 20	PAb	62%	13%	30%	90%	12%	16%	62%			4%
	GL30	UAb	0%	4%	76%	66%	22%	19%	12%			13%
ď		PAb	42%	24%	42%	95%	14%	9%	94%			10%
N S	FROM-GLC	UA <sub>b</sub>	0%	2%	6%	59%	90%	8%	8%			6%
21	ENIE	PAb				94%			93%			
MC (S2)		UA <sub>b</sub>				41%			6%			
	GSW seasonality	PAb								65%	23%	
-		UA <sub>b</sub>								6%	27%	
<b>NT</b>	GSW/ v1 2	PAb								74%	23%	
<u> </u>	GSW_v1_2	UA <sub>b</sub>								6%	44%	
	GHS BU S1	PAb		24%								
	GHS BU S1	UA <sub>b</sub>		0%								
	GI 30	PAb	42%	29%	26%	86%	14%	19%	57%			6%
		UAb	0%	2%	75%	68%	23%	19%	14%			13%
ď	FROM-GLC	PAb	8%	66%	37%	93%	15%	15%	94%			13%
N N		UA <sub>b</sub>	0%	1%	6%	62%	86%	11%	10%			6%
21	ENE	PAb				91%			91%			
(S2)		UAb				42%			8%			
TS (	GSW seasonality	PAb								65%	24%	
5		UA <sub>b</sub>								8%	26%	
STN	GSW/ v1 2	PAb								73%	23%	
_		UAb								7%	42%	
	GHS BU S1	PAb		51%								
	GHS BU S1	UA <sub>b</sub>		0%								

Cesa	Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>Figh</b> resolution
	Issue	Date	Page	and cover
	2.rev.1	01/02/2023	16	cci

#### 3.1.2.4 Table 8. UA<sub>b</sub> and PA<sub>b</sub> for Amazon 21KXT – RF (S1) and SVM (S2)

Algorith	Datasat	Inde	Barelan	Built-	Croplan	Fores	Grasslan	Shrublan	Wate	Water	Water	Wetlan	Wetland
m	Dataset	x	d	up	d	t	d	d	r	Permanent	Seasonal	d	Herbaceous
	CI 20	$PA_b$	0%	45%	4%	74%	11%	25%	64%			1%	
	GLSU	UAb	0%	6%	97%	60%	0%	8%	27%			4%	
	EPOM CLC	$PA_b$	27%	51%	9%	79%	39%	37%	88%			12%	
	FROM-GLC	UAb	0%	3%	4%	77%	98%	8%	23%			12%	
F	ManBiomas	PAb	0%	60%	18%	76%	38%	28%	81%				5%
X	марыоттаз	UAb	0%	5%	3%	76%	98%	5%	22%				4%
(S1) 21	ENIE	$PA_b$				41%			5%				
	FINF	UAb				80%			5%				
KF (:	GSW	$PA_b$								58%	22%		
œ	seasonality	UAb								35%	6%		
		$PA_b$								64%	17%		
	0300_01_2	UAb								27%	10%		
	GHS BU S1	$PA_b$		56%									
		UAb		4%									
	CL 20	$PA_b$	0%	29%	25%	79%	41%	13%	39%			18%	
	GLSU	UAb	0%	21%	91%	55%	4%	8%	28%			36%	
	EPOM CLC	$PA_b$	17%	40%	47%	86%	40%	24%	71%			61%	
	FROM-GLC	UAb	0%	16%	4%	74%	94%	9%	30%			16%	
х	ManPiomac	$PA_b$	1%	42%	65%	83%	40%	17%	59%				56%
1 K	марыоттаз	UAb	0%	18%	3%	73%	95%	5%	22%				23%
) 2:	ENIE	$PA_b$				76%			4%				
(S2	FINF	UAb				76%			4%				
Σ	GSW	$PA_b$								70%	18%		
۶۷	seasonality	UAb								36%	5%		
		$PA_b$								77%	14%		
	G246_71_2	UA <sub>b</sub>								27%	10%		
		PAb		36%									
		UA <sub>b</sub>		12%									

Cesa	Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>Figh</b> resolution
	Issue	Date	Page	and cover
	2.rev.1	01/02/2023	17	CCI

3.1.2.5 Table 9. UA<sub>b</sub> and PA<sub>b</sub> for Amazon 21KXT – LOGP and MRF decision fusion algorithms

Algorith	Datasat	Inde	Barelan	Built-	Croplan	Fores	Grasslan	Shrublan	Wate	Water	Water	Wetlan	Wetland
m	Dataset	х	d	up	d	t	d	d	r	Permanent	Seasonal	d	Herbaceous
		$PA_b$	0%	40%	24%	81%	43%	12%	41%			19%	
	GL30	UAb	0%	27%	91%	56%	4%	8%	25%			35%	
		$PA_b$	20%	51%	50%	88%	43%	23%	74%			61%	
	FROM-GLC	UAb	0%	19%	4%	75%	95%	9%	25%			15%	
	ManBiomas	PAb	0%	58%	68%	85%	43%	16%	63%				56%
СХТ	марыоттаз	UAb	0%	24%	3%	74%	96%	5%	20%				22%
21	ENE	PAb				78%			4%				
<u>д</u>	FINF	UAb				77%			4%				
ΓÕ	GSW	$PA_b$								71%	20%		
	seasonality	UA <sub>b</sub>								35%	5%		
		PAb								77%	16%		
	0300_01_2	UA <sub>b</sub>								27%	9%		
	GHS BU S1	PAb		50%									
		UAb		16%									
	GL30	$PA_b$	0%	42%	24%	82%	45%	11%	41%			19%	
		UAb	0%	31%	92%	56%	4%	8%	29%			35%	
	EPOM CLC	$PA_b$	19%	53%	50%	89%	45%	22%	74%			61%	
	FROIVI-GLC	UAb	0%	22%	4%	75%	95%	10%	30%			16%	
	ManBiomac	PAb	0%	61%	69%	86%	44%	15%	63%				57%
хт	марыоттаз	UAb	0%	28%	3%	75%	96%	5%	23%				23%
11 K	ENIE	$PA_b$				79%			4%				
κF 2	FINE	UA <sub>b</sub>				77%			4%				
MF	GSW	PAb								71%	19%		
	seasonality	UA <sub>b</sub>								37%	5%		
		$PA_b$								78%	14%		
	0300_01_2	UAb								28%	10%		
		$PA_b$		53%									
		UA <sub>b</sub>		19%									

	Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>mage</b> high resolution
<b>esa</b>	Issue	Date	Page	and cover
	2.rev.1	01/02/2023	18	CCI

## 3.1.2.6 Table 10. UA<sub>b</sub> and PA<sub>b</sub> for Amazon 21KXT – LSTM - TS (S2) and LSTM - MC (S2) algorithms

Algorithm	Dataset	Index	Bareland	Built-up	Cropland	Forest	Grassland	Shrubland	Water	Water Permanent	Water Seasonal	Wetland	Wetland Herbaceous
		PAb	0%	39%	22%	76%	35%	16%	50%			21%	
	GL30	$UA_b$	0%	10%	92%	57%	4%	8%	15%			35%	
		$PA_b$	14%	51%	38%	84%	33%	29%	83%			55%	
Ţ	FROIVI-GLC	$UA_b$	0%	7%	4%	78%	94%	9%	15%			12%	
N 1	ManBiomas	$PA_b$	3%	55%	51%	81%	33%	22%	72%				58%
2) 2.	марыоттаз	UAb	0%	9%	3%	77%	95%	5%	11%				20%
(S2	ENIE	PAb				73%			5%				
ИC	FINF	UAb				78%			2%				
-	GSW cosconslity	$PA_b$								83%	13%		
ΣL	GSW seasonality	$UA_b$								20%	2%		
rs		$PA_b$								88%	11%		
	G3W_V1_2	$UA_b$								15%	3%		
	GHS BU S1 -	$PA_b$		47%									
		UAb		6%									
	GI 30	PAb	0%	41%	19%	73%	32%	17%	50%			20%	
	GLSU	UAb	0%	11%	92%	56%	4%	7%	12%			34%	
		$PA_b$	16%	54%	37%	81%	28%	31%	82%			53%	
E	FROIVI-GLC	UA <sub>b</sub>	0%	8%	4%	76%	95%	8%	12%			12%	
Ŷ.	ManRiomas	PAb	3%	57%	50%	78%	28%	23%	73%				56%
21	марыоттаз	UAb	0%	9%	3%	75%	95%	4%	9%				20%
[S2]	ENIE	PAb				71%			5%				
TS (	I INI	UA <sub>b</sub>				78%			2%				
V	GSW cosconslity	$PA_b$								76%	26%		
STA	GSW seasonality	$UA_b$								28%	2%		
نڌ		PAb								83%	22%		
	0300_01_2	UAb								21%	4%		
		PAb		49%									
	GHS BU S1	UA <sub>b</sub>		6%									

	Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>mage</b> high resolution
<b>esa</b>	Issue	Date	Page	and cover
	2.rev.1	01/02/2023	19	CCI

# 3.1.2.7 Table 11. UA<sub>b</sub> and PA<sub>b</sub> for Africa 37PCP – RF (S1) and SVM (S2) algorithms

Algorithm	Dataset	Index	Bareland	Built-up	Cropland	Forest	Grassland	Shrubland	Water	Water Permanent	Water Seasonal	Wetland
	CI 20	$PA_b$	0%	58%	53%	41%	13%	4%	99%			31%
	GLSU	UA <sub>b</sub>	0%	2%	88%	22%	12%	2%	96%			25%
		$PA_b$	23%	85%	55%	59%	13%	7%	100%			8%
	FROM-GLC	UA <sub>b</sub>	2%	0%	87%	5%	7%	28%	96%			4%
PCF	ENIE	PAb				26%			100%			
37		UA <sub>b</sub>				12%			95%			
(S1)	GSW seasonality	$PA_b$								97%	80%	
RF	05W Seasonality	UA <sub>b</sub>								100%	25%	
	GSW/ v1 2	$PA_b$								97%	66%	
	0300_01_2	UA <sub>b</sub>								100%	33%	
	GHS BU S1	$PA_b$		84%								
	GHS BU S1	UA <sub>b</sub>		0%								
	GL30	PAb	0%	46%	53%	32%	34%	8%	99%			36%
		UAb	0%	10%	89%	27%	18%	1%	98%			25%
	FROM-GLC	$PA_b$	53%	92%	56%	89%	42%	30%	100%			10%
e.		UA <sub>b</sub>	17%	0%	89%	13%	14%	33%	97%			4%
7PC	ENE	PAb				27%			100%			
2) 3		UA <sub>b</sub>				21%			96%			
(S:	GSW seasonality	$PA_b$								96%	90%	
SVM	Gow Seasonancy	UA <sub>b</sub>								100%	29%	
	GSW v1 2	$PA_b$								96%	75%	
		UA <sub>b</sub>								100%	39%	
	GHS BU S1	$PA_b$		72%								
	010 00 01	UA <sub>b</sub>		2%								

Cesa	Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>Figh</b> resolution
	Issue	Date	Page	and cover
	2.rev.1	01/02/2023	20	CCI

3.1.2.8 Table 12. UA<sub>b</sub> and PA<sub>b</sub> Africa 37PCP – LOGP and MRF decision fusion algorithms

Algorithm	Dataset	Index	Bareland	Built-up	Cropland	Forest	Grassland	Shrubland	Water	Water Permanent	Water Seasonal	Wetland
	CI 20	$PA_b$	0%	50%	56%	35%	32%	7%	99%			38%
	GL30	UAb	0%	9%	89%	29%	18%	1%	98%			32%
		$PA_b$	52%	95%	59%	90%	38%	28%	100%			10%
	FROM-GLC	$UA_b$	19%	0%	89%	13%	13%	34%	97%			5%
Ð		$PA_b$				28%			100%			
37P	FINF	UA <sub>b</sub>				21%			96%			
6	CSW cosconslity	$PA_b$								97%	91%	
2	GSW seasonality	$UA_b$								100%	34%	
	GSW $y1$ $2$	$PA_b$								98%	77%	
	0300_01_2	UA <sub>b</sub>								100%	47%	
		PAb		77%								
	GHS BO ST	UA <sub>b</sub>		2%								
	GL30	PAb	0%	52%	57%	36%	32%	6%	99%			38%
		UA <sub>b</sub>	0%	11%	89%	30%	18%	1%	98%			32%
	FROM-GLC	$PA_b$	53%	96%	60%	91%	38%	28%	100%			10%
		UA <sub>b</sub>	19%	0%	89%	13%	13%	35%	97%			5%
9	FNF	$PA_b$				28%			100%			
37P		UA <sub>b</sub>				22%			96%			
R	GSW seasonality	$PA_b$								97%	92%	
Σ		UA <sub>b</sub>								100%	35%	
	GSW_v1_2	$PA_b$								98%	77%	
		UA <sub>b</sub>								100%	47%	
		$PA_b$		79%								
	013 00 31	$UA_b$		2%								

	Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>Figh</b> resolution
<b>esa</b>	Issue	Date	Page	and cover
	2.rev.1	01/02/2023	21	

## 3.1.2.9 Table 13. UA<sub>b</sub> and PA<sub>b</sub> for Africa 37PCP – LSTM - TS (S2) and LSTM - MC (S2) algorithms

Algorithm	Dataset	Index	Bareland	Built-up	Cropland	Forest	Grassland	Shrubland	Water	Water Permanent	Water Seasonal	Wetland
	01.00	$PA_b$	0%	47%	47%	31%	24%	13%	99%			50%
	GL30	$UA_b$	0%	7%	90%	24%	18%	1%	98%			17%
8		PAb	61%	91%	49%	91%	35%	44%	100%			17%
7PC	FROM-GLC	$UA_b$	11%	0%	90%	12%	16%	29%	97%			3%
ы Э		$PA_b$				27%			100%			
(S2	FINF	UA <sub>b</sub>				19%			96%			
Ĕ	GSW seasonality	$PA_b$								93%	84%	
Ś	05W Seasonality	UA <sub>b</sub>								100%	19%	
ILS	GSW/ v1 2	$PA_b$								93%	70%	
_	0300_01_2	UA <sub>b</sub>								100%	25%	
	GHS BU S1	$PA_{b}$		71%								
		UA <sub>b</sub>		2%								
	GI 30	$PA_b$	0%	49%	43%	35%	22%	20%	99%			47%
	GLSU	UA <sub>b</sub>	0%	6%	90%	22%	16%	1%	97%			13%
	FROM-GLC	$PA_b$	60%	91%	46%	92%	31%	40%	100%			13%
Ð		UA <sub>b</sub>	14%	0%	92%	10%	13%	27%	97%			2%
i) 37F	FNF	$PA_b$				30%			100%			
(S2		$UA_b$				18%			96%			
_ <b>T</b> S	CSW cooconality	$PA_b$								94%	88%	
Σ	GSW seasonality	UA <sub>b</sub>								100%	20%	
[]		$PA_b$								94%	75%	
	0300_01_2	UAb								100%	28%	
		PAb		72%								
		UAb		1%								

	Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>Figh</b> resolution
<b>esa</b>	Issue	Date	Page	and cover
	2.rev.1	01/02/2023	22	

# 3.1.2.10 Table 14. UA<sub>b</sub> and PA<sub>b</sub> for Siberia 42WXS – RF (S1) and SVM (S2) algorithms – part 1

Algorithm	Dataset	Index	Bareland	Built-up	Forest	Forest deciduous broadleaf	Forest evergreen needleleaf	Grassland	Lichens and Mosses
		PAb	47%	0%	77%			24%	5%
	PROIVI-GLC	UA <sub>b</sub>	9%	0%	90%			73%	5%
	ESA DUE ClobDormafrost	PAb	22%			4%	33%	46%	53%
	ESA DUE GIODPermanost	UA <sub>b</sub>	17%			5%	35%	12%	0%
S	CI 20	PAb	29%	0%	40%			10%	0%
XX	9130	UAb	3%	0%	88%			4%	0%
42	ENIE	PAb			75%				
51)	FINE	UAb			66%				
E (	CSW cooconality	$PA_b$							
£	GSW seasonality	UA <sub>b</sub>							
		PAb							
	0300_01_2	UAb							
		$PA_{b}$		0%					
	0113 80 31	UAb		0%					
		PAb	58%	0%	69%			16%	5%
		UAb	19%	0%	79%			84%	6%
	ESA DUE ClobBormafrost	$PA_{b}$	1%			2%	25%	84%	89%
	ESA DUE GIODPermanost	UAb	2%			2%	35%	31%	2%
XS	CI 30	PAb	80%	0%	37%			6%	0%
ZM	0130	UAb	14%	0%	80%			4%	0%
(	ENIE	PAb			66%				
(S2		UA <sub>b</sub>			57%				
Σ	GSW seasonality	PAb							
SV	GSW seasonality	UAb							
		PAb							
	0300_01_2	UAb							
		PAb		0%					
		UA <sub>b</sub>		0%					

Cesa	Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>Figh</b> resolution
	Issue	Date	Page	and cover
	2.rev.1	01/02/2023	23	

# 3.1.2.11 Table 15. UA<sub>b</sub> and PA<sub>b</sub> for Siberia 42WXS – RF (S1) and SVM (S2) algorithms – part 2

Algorithm	Dataset	Index	Permanent ice and snow	Shrubland	Shrubland evergreen	Water	Water Permanent	Water Seasonal	Wetland
	FROM-GLC	PAb	0%	53%		92%			40%
	TROW-GEC	UAb	0%	1%		63%			13%
	ESA DUE ClabBormafrost	$PA_{b}$			19%		61%	38%	28%
	ESA DUE GIODPermanost	UA <sub>b</sub>			58%		96%	29%	22%
S	6130	$PA_{b}$		0%		88%			33%
XX X	GLSU	UA <sub>b</sub>		0%		63%			76%
42\		PAb				53%			
31)	FINE	UA <sub>b</sub>				40%			
F (5	CCM/ as a second lite	PA <sub>b</sub>					63%	45%	
2	GSW seasonality	UA <sub>b</sub>					93%	16%	
	CON1 4 2	PA <sub>b</sub>					62%	33%	
	GSW_V1_2	UA <sub>b</sub>					96%	12%	
		PA <sub>b</sub>							
	GHS BO ST	UAb							
	FROM CLC	PAb	0%	43%		96%			50%
	FROM-GLC	UAb	0%	0%		56%			15%
		PA <sub>b</sub>			25%		56%	47%	49%
	ESA DUE GlobPermafrost	UA <sub>b</sub>			62%		88%	25%	33%
(S	0100	PAb		0%		89%			30%
S.	GL30	UA <sub>b</sub>		0%		55%			61%
942	ENE	PAb				53%			
[S2]	FINE	UA <sub>b</sub>				34%			
Σ		PA <sub>b</sub>					55%	40%	
SV	GSW seasonality	UA <sub>b</sub>					82%	11%	
		PA <sub>b</sub>					55%	34%	
	GSW_v1_2	UAb					86%	9%	
		PAb							
	GH2 RO 21	UA <sub>b</sub>							

	Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>Figh</b> resolution
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## 3.1.2.12 Table 16. UA<sub>b</sub> and PA<sub>b</sub> for Siberia 42WXS – LOGP and MRF decision fusion algorithms – part 1

Algorithm	Dataset	Index	Bareland	Built-up	Forest	Forest deciduous broadleaf	Forest evergreen needleleaf	Grassland	Lichens and Mosses
		$PA_b$	59%	0%	74%			18%	3%
	FROIVI-GLC	UA <sub>b</sub>	8%	11%	90%			78%	4%
	ESA DUE ClobPormafrost	$PA_b$	3%			6%	13%	64%	64%
	ESA DUE GIODPermanost	UAb	2%			5%	24%	20%	1%
(0)	CI 20	$PA_b$	81%	23%	39%			7%	0%
SXA	GLSU	UAb	15%	23%	87%			4%	0%
42V	ENIE	$PA_b$			71%				
d	FINE	UAb			65%				
0	GSW cosconslity	$PA_b$							
_	GSW seasonality	UAb							
		$PA_b$							
	0300_01_2	UAb							
				34%					
	0113 80 31	UAb		9%					
		$PA_b$	58%	29%	72%			15%	2%
		UAb	10%	4%	88%			79%	3%
	ESA DUE GlobPermafrost	$PA_b$	3%			9%	6%	66%	66%
		UAb	2%			6%	20%	25%	1%
	GI 30	$PA_b$	81%	23%	38%			6%	0%
VXS	0150	UAb	7%	23%	87%			4%	0%
-2M	ENIE	$PA_b$			68%				
8F 4		UAb			63%				
ĽΣ	GSW seasonality	$PA_b$							
	USW seasonality	UAb							
		$PA_b$							
	0300_01_2	UAb							
		$PA_b$		35%					
		UA <sub>b</sub>		9%					

Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>Figh</b> resolution
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### 3.1.2.13 Table 17. UA<sub>b</sub> and PA<sub>b</sub> for Siberia 42WXS – LOGP and MRF decision fusion algorithms – part 2

Algorithm	Dataset	Index	Permanent ice and snow	Shrubland	Shrubland evergreen	Water	Water Permanent	Water Seasonal	Wetland
	FROM-GLC	PAb	0%	59%		97%			46%
		UA <sub>b</sub>	0%	1%		58%			13%
ESA DUE GlobPermafrost		$PA_b$			23%		68%	58%	38%
	ESA DUE GIODPermanost	$UA_b$			64%		97%	38%	24%
(0)	CI 20	PAb		0%		93%			36%
XX	GLSU	UAb		0%		58%			72%
12V	ENIE	PAb				57%			
d D	FINE	UAb				37%			
Ő	CSW conconnelity	$PA_b$					70%	59%	
_	GSW seasonality	UAb					96%	17%	
	CSW/ 1/1 - 2	$PA_b$					68%	47%	
	G3VV_V1_2	UAb					99%	14%	
		PAb							
	GH3 BU 31	UAb							
	EBONA CLC	$PA_b$	0%	58%		97%			50%
	FROM-GLC	UAb	0%	0%		58%			13%
	ESA DUE ClobBormafrost	$PA_b$			25%		68%	59%	44%
	ESA DUE GIODPermanost	UAb			65%		98%	38%	24%
	CI 30	$PA_b$		0%		94%			39%
/XS	GLSU	UAb		0%		58%			69%
2 4		$PA_b$				57%			
Г 4	FINE	UAb				37%			
Ξ	CSW conconnelity	$PA_b$					70%	60%	
	GSW seasonality	UAb					96%	17%	
		PAb					68%	48%	
	0300_01_2	UAb					99%	14%	
		PAb							
		UA <sub>b</sub>							

	Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>Figh</b> resolution
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## 3.1.2.14 Table 18. UA<sub>b</sub> and PA<sub>b</sub> for Siberia 42WXS – LSTM – TS algorithm

Algorith m	Dataset	Index	Barelan d	Built-up	Forest	Forest deciduo us broadle af	Forest evergre en needlel eaf	Grassla nd	Lichens and Mosses	Perman ent ice and snow	Shrubla nd	Shrubla nd evergre en	Water	Water Perman ent	Water Seasona I	Wetlan d
	FROM-	PAb	57%	0%	79%			14%	6%	0%	49%		98%			50%
	GLC	UA <sub>b</sub>	8%	0%	84%			87%	6%	0%	0%		57%			20%
	ESA DUE GlobPe	$PA_b$	1%			3%	14%	84%	92%			31%		90%	58%	48%
NXS	rmafro st	$UA_b$	1%			2%	26%	35%	2%			67%		92%	58%	42%
42\	CI 20	$PA_b$	78%	0%	42%			4%	0%		13%		93%			25%
S2)	UL30	UA <sub>b</sub>	6%	0%	84%			3%	0%		0%		57%			71%
TS (	ENE	PAb			74%								57%			
V		UA <sub>b</sub>			59%								36%			
TSTN	GSW season	$PA_b$												88%	43%	
	ality	UA <sub>b</sub>												86%	17%	
	GSW_v	$PA_b$												87%	42%	
	1_2	UAb												90%	17%	
	GHS BU	PAb		0												
	S1	UAb		0%												

	Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>Figh</b> resolution
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# 3.1.2.15 Table 19. Average UA<sub>b</sub> per fusion algorithm and RR region

Algorithm	RR tile	Bareland	Built-up	Cropland	Forest	Forest deciduous broadleaf	Forest evergreen needleleaf	Grassland	Lichens and Mosses	Permanent ice and snow	Shrubland	Shrubland evergreen	Water	Water permanent	Water seasonal	Wetland	Wetland Herbaceous
MRF	21KUQ	0	0.08	0.4	0.54			0.57			0.15		0.2	0.16	0.32	0.19	
LOGP	21KUQ	0	0.08	0.4	0.54			0.57			0.15		0.19	0.16	0.33	0.19	
MRF	21KXT	0	0.25	0.33	0.71			0.65			0.08		0.22	0.32	0.08	0.26	0.23
LOGP	21KXT	0	0.22	0.33	0.7			0.65			0.07		0.18	0.31	0.07	0.25	0.22
MRF	37PCP	0.1	0.04	0.89	0.22			0.15			0.18		0.97	1	0.41	0.18	
LOGP	37PCP	0.1	0.04	0.89	0.21			0.15			0.18		0.97	1	0.4	0.18	
MRF	42WXS	0.06	0.12		0.79	0.06	0.2	0.36	0.01	0	0	0.65	0.51	0.98	0.23	0.35	
LOGP	42WXS	0.05	0.12		0.81	0.05	0.24	0.34	0.02	0	0	0.64	0.51	0.97	0.23	0.36	
MRF	39	2	4	3	3	1	0	4	1	1	3	1	4	4	4	3	1
LOGP	26	1	1	3	3	0	1	2	1	1	3	0	2	2	2	4	0

Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>Figh</b> resolution
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# 3.1.2.16 Table 20. Average UA $_{\rm b}$ per classification algorithm and RR region

Algorithm	RR tile	Bareland	Built-up	Cropland	Forest	Forest deciduous broadleaf	Forest evergreen needleleaf	Grassland	Lichens and Mosses	Permanent ice and snow	Shrubland	Shrubland evergreen	Water	Water permanent	Water seasonal	Wetland	Wetland Herbaceous
LSTM - MC (S2)	21KUQ	0	0.02	0.41	0.56			0.56			0.13		0.09	0.06	0.36	0.1	
RF (S1)	21KUQ	0	0	0.39	0.61			0.55			0.18		0.18	0.01	0.27	0.14	
SVM (S2)	21KUQ	0	0.05	0.4	0.53			0.56			0.14		0.13	0.1	0.33	0.13	
LSTM - TS (S2)	21KUQ	0	0.01	0.4	0.57			0.55			0.15		0.11	0.07	0.34	0.1	
LSTM - MC (S2)	21KXT	0	0.08	0.33	0.73			0.64			0.07		0.11	0.18	0.02	0.24	0.2
RF (S1)	21KXT	0	0.04	0.35	0.73			0.65			0.07		0.19	0.31	0.08	0.08	0.04
SVM (S2)	21KXT	0	0.17	0.33	0.70			0.65			0.07		0.21	0.32	0.08	0.26	0.23
LSTM - TS (S2)	21KXT	0	0.08	0.33	0.71			0.64			0.06		0.09	0.24	0.03	0.23	0.2
LSTM - MC (S2)	37PCP	0.06	0.03	0.9	0.19			0.17			0.15		0.97	1	0.22	0.1	
RF (S1)	37PCP	0.01	0.01	0.88	0.13			0.1			0.15		0.96	1	0.29	0.14	
SVM (S2)	37PCP	0.09	0.04	0.89	0.2			0.16			0.17		0.97	1	0.34	0.15	
LSTM - TS (S2)	37PCP	0.08	0.02	0.91	0.17			0.15			0.14		0.97	1	0.24	0.08	
RF (S1)	42WXS	0.1	0		0.81	0.05	0.35	0.3	0.02	0	0	0.58	0.56	0.95	0.19	0.37	
SVM (S2)	42WXS	0.12	0		0.72	0.02	0.35	0.4	0.03	0	0	0.62	0.48	0.85	0.14	0.36	
LSTM - TS (S2)	42WXS	0.05	0.25		0.76	0.02	0.26	0.42	0.03	0	0	0.67	0.5	0.89	0.31	0.44	
LSTM - MC (S2)	6			2	1			1			1				1		
LSTM - TS (S2)	18		1	1	2	1		3	1	1	1	1	2	2	1	1	
SVM (S2)	23	1	3	2		1	1	2	1	1	1		3	3	1	2	1

	Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>Figh</b> resolution
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# 3.1.2.17 Table 21. Average PA<sub>b</sub> per fusion algorithm and RR region

Algorithm	RR tile	Bareland	Built-up	Cropland	Forest	Forest deciduous broadleaf	Forest evergreen needleleaf	Grassland	Lichens and Mosses	Permanent ice and snow	Shrubland	Shrubland evergreen	Water	Water permanent	Water seasonal	Wetland	Wetland Herbaceous
MRF		0.62	0.05	0.36	0.95			0.26			0.05		0.77	0.78	0.08	0.06	
LOGP	21KUQ	0.62	0.07	0.35	0.94			0.26			0.06		0.76	0.77	0.08	0.06	
MRF		0.06	0.52	0.48	0.84			0.45			0.16		0.45	0.74	0.16	0.4	0.57
LOGP	21KXT	0.07	0.5	0.47	0.83			0.43			0.17		0.45	0.74	0.18	0.4	0.56
MRF		0.26	0.76	0.58	0.52			0.35			0.17		1	0.98	0.84	0.24	
LOGP	37PCP	0.26	0.74	0.57	0.51			0.35			0.18		1	0.98	0.84	0.24	
MRF		0.47	0.29		0.59	0.09	0.06	0.29	0.23	0	0.29	0.25	0.83	0.69	0.56	0.44	
LOGP	42WXS	0.47	0.28		0.61	0.06	0.13	0.3	0.22	0	0.3	0.23	0.82	0.69	0.55	0.4	
MRF	36	4	3	3	3	1	0	3	1	0	2	1	4	3	3	4	1
LOGP	23	2	1	0	1	0	1	2	0	0	4	0	3	4	2	3	0

	Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	high resolution
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# 3.1.2.18 Table 22. Average $PA_b$ per classification algorithm and RR region

Algorithm	RR tile	Bareland	Built-up	Cropland	Forest	Forest deciduous broadleaf	Forest evergreen needleleaf	Grassland	Lichens and Mosses	Permanent ice and snow	Shrubland	Shrubland evergreen	Water	Water permanent	Water seasonal	Wetland	Wetland Herbaceous
LSTM - MC (S2)		0.52	0.2	0.36	0.93			0.13			0.12		0.83	0.69	0.23	0.07	
RF (S1)	211/10	0.41	0.02	0.27	0.77			0.22			0.18		0.3	0	0.07	0.03	
SVM (S2)	ZIKUQ	0.59	0.07	0.36	0.94			0.22			0.05		0.77	0.78	0.08	0.07	
LSTM - TS (S2)		0.25	0.49	0.32	0.9			0.14			0.17		0.81	0.69	0.24	0.09	
LSTM - MC (S2)		0.1	0.48	0.37	0.79			0.34			0.22		0.53	0.85	0.12	0.38	0.58
RF (S1)	21VVT	0.13	0.53	0.1	0.67			0.29			0.3		0.6	0.61	0.19	0.06	0.05
SVM (S2)		0.1	0.37	0.46	0.81			0.4			0.18		0.43	0.73	0.16	0.39	0.56
LSTM - TS (S2)		0.11	0.5	0.35	0.76			0.29			0.24		0.52	0.8	0.24	0.37	0.56
LSTM - MC (S2)		0.37	0.7	0.48	0.5			0.3			0.28		1	0.93	0.77	0.33	
RF (S1)	27000	0.18	0.76	0.54	0.42			0.13			0.05		0.99	0.97	0.73	0.19	
SVM (S2)	37FCF	0.33	0.7	0.54	0.49			0.38			0.19		1	0.96	0.83	0.23	
LSTM - TS (S2)		0.36	0.71	0.44	0.52			0.27			0.3		1	0.94	0.82	0.3	
RF (S1)		0.32	0		0.64	0.04	0.33	0.27	0.24	0	0.33	0.19	0.77	0.62	0.39	0.34	
SVM (S2)	42WXS	0.47	0		0.58	0.02	0.25	0.35	0.35	0	0.28	0.25	0.79	0.55	0.4	0.43	
LSTM - TS (S2)		0.45	0		0.65	0.03	0.14	0.34	0.37	0	0.31	0.31	0.82	0.88	0.48	0.41	
LSTM - MC (S2)	8	1		1									3	1		1	1
LSTM - TS (S2)	20	1	3		2	1			1		4	1	2	1	3	1	
SVM (S2)	20	2	1	3	2		1	4		1			1	2	1	2	

	Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>Figh</b> resolution
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#### 3.1.2.19 Table 23. Mean and standard deviation of UA and PA of SVM algorithm

RR tile	Statistic	Index	Bareland	Built-up	Cropland	Forest	Forest deciduous broadleaf	Forest evergreen needleleaf	Grassland	Lichens and Mosses	Permanent ice and snow	Shrubland	Shrubland evergreen	Water	Water permanent	Water seasonal	Wetland	Wetland Herbaceous
	mean	PA	0.59	0.07	0.36	0.94			0.22			0.04		0.77	0.78	0.08	0.07	
21KUQ	mean	UA	0	0.05	0.4	0.53			0.56			0.14		0.13	0.1	0.33	0.13	
	mean	PA	0.06	0.37	0.46	0.81			0.4			0.18		0.43	0.74	0.16	0.4	0.56
21KXT	mean	UA	0	0.17	0.33	0.7			0.64			0.07		0.21	0.32	0.08	0.26	0.23
	mean	PA	0.26	0.7	0.55	0.49			0.38			0.19		1	0.96	0.82	0.23	
37PCP	mean	UA	0.08	0.04	0.89	0.2			0.16			0.17		0.97	1	0.34	0.14	
	mean	PA	0.46	0		0.57	0.02	0.25	0.35	0.31	0	0.22	0.25	0.79	0.55	0.4	0.43	
42WXS	mean	UA	0.12	0		0.72	0.02	0.35	0.4	0.03	0	0	0.62	0.48	0.85	0.15	0.36	
	std	PA	0.07	0.04	0.08	0.02			0.03			0.02		0.21	0.05	0.01	0.04	
21KUQ	std	UA	0	0.04	0.47	0.13			0.47			0.09		0.03	0	0.13	0.06	
	std	PA	0.1	0.06	0.2	0.04			0.01			0.06		0.29	0.05	0.03	0.3	
21KXT	std	UA	0	0.04	0.51	0.1			0.52			0.02		0.12	0.06	0.04	0.14	
	std	PA	0.37	0.23	0.02	0.34			0.06			0.16		0.01	0	0.11	0.18	
37PCP	std	UA	0.12	0.05	0	0.07			0.03			0.23		0.01	0	0.07	0.15	
	std	PA	0.41	0		0.18			0.42	0.5		0.3		0.23	0.01	0.07	0.11	
42WXS	std	UA	0.09	0		0.13			0.41	0.03		0		0.12	0.03	0.09	0.23	

Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>mage</b> high resolution
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#### 3.1.3 Conclusions

This section provides insight into performance of the algorithms as well as into benchmark accuracy. Since the results are based on the inter-comparison with existing land cover products term "the best" is equivalent to "the best agreement with the other products".

#### 3.1.3.1 Algorithm comparison – RR products

With respect to the algorithm comparison in case of Amazon (21KXT and 21KUQ) only optical algorithms – SVM, LSTM-TS and LSTM – MC - were compared, while for 37PCP and 42WXS all algorithms, including RF, were compared in terms of their OA<sub>b</sub> scores.

SVM (S2) algorithm from optical chain is the best according to OA<sub>b</sub> (Table 2) in all regions except in 42WXS (Siberia) where RF (S1) is slightly better. From the point of view of class indexes, UA<sub>b</sub> and PA<sub>b</sub>, RF (S1) was not considered for comparison with other algorithms because size discrepancy of RF (S1) prototypes makes it difficult to summarize results. Only in case of Siberia SVM (S2) was compared with RF (S1) because only in this case OA<sub>b</sub> was somewhat higher for RF (S1) than for the SVM (S2). The SVM (S2) and RF (S1) comparison relies on Table 14 and Table 15 and it suggest that better performance of RF (S1) can be attributed to the more successful classification of Forest, Forest deciduous broadleaf, Forest evergreen needleleaf, and Shrubland. Nevertheless, SVM was more successful with Bareland, Grassland, Lichens and Mosses, Shrubland evergreen and Wetland, so the difference in performance of the two algorithms is small.

Regarding comparison of optical chain algorithms from the point of view of individual class indexes they were compared taking into consideration count of number of times when an algorithm had better average  $PA_b$  or  $UA_b$  score than the others in a region for a class. Average  $UA_b$  (Table 20) is showing that SVM (S2) was better than other two algorithms 23 times, LSTM-TS (S2) 18 times, while LSTM-MC (S2) only 6 times. Looking at the average  $PA_b$  (Table 22), SVM (S2) and LSTM-TS (S2) were better than other algorithms equal number of times - 20, while LSTM - MS (S2) 8 times. Therefore, average  $PA_b$  or  $UA_b$  are also indicating that SVM (S2) is performing better than other algorithms.

Regarding fusion algorithms, MRF had slightly better scores than LOGP (Table 3, Table 19 and Table 21). In addition, success of fusion algorithm was estimated based on the difference between  $OA_b$  of fusion algorithms and of SVM and RF algorithms since these are the two algorithms involved in the fusion (Table 4). From Table 4 it can be seen that in most of the cases the yield from fusion is positive. However, in case of 42WXS there are some negative values. That is probably due to the fact that MRF gives more weight to the optical chain outputs, while in the case of 42WXS SAR chain outputs (i.e. RF (S1)) had better  $OA_b$  score.

#### 3.1.3.2 Benchmark accuracy – RR products

From the point of view of benchmark accuracy, for binary maps that are specifically derived for certain class – FNF, GHS BU S1, GSW seasonality,  $GSW_v1_2 - OA_b$  is very high due to the presence of the class that represent all the other classes but the one of interest for the map. Therefore  $OA_b$  for these maps is not informative, and only PA<sub>b</sub> and UA<sub>b</sub> were taken into consideration for the following conclusions.

On average  $OA_b$  with multiple-class existing maps is around 50% being the highest in comparison of SVM algorithm with FROM-GLC map (60%) in 37PCP. Agreement of 60% can be considered moderately good given that also other map contains certain errors.

Regarding individual accuracy indexes the classification are interpreted as "excellent" if both scores  $PA_b$  and  $UA_b$  (in the Table 5- Table 18, ) are above 90%, "well" if the scores are between 70% and 90% and "relatively good" if the scores are between 50% and 70%.

Forest is classified relatively good or well by majority of the algorithms in all regions except in 37PCP. In case of 21KUQ and 42WXS forest is classified relatively good, while in the case of 21KXT it is well classified.

In case of 37PCP Water and Water Permanent have excellent accuracy. This is probably due to the big water body present in the 37PCP region. The large water body might be the reason why also  $OA_b$  is higher for 37PCP than for the other tiles. Also Cropland is relatively good classified in 37PCP.

For 42WXS Forest, Water, Water Permanent are classified relatively good.

Other classes either have low scores or the scores from comparison with different existing datasets are contradictory therefore it is not possible to derive conclusions.

Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>migh</b> resolution
Issue	Date	Page	and cover
2.rev.1	01/02/2023	33	CCI

Moreover, standard deviation was computed for  $UA_b$  and  $PA_b$  for SVM (S1) algorithm (Table 23) in order to have insight into variation of scores. Large variation among the scores indicate that there is large variation in the existing maps regarding a certain class, therefore at least some of the maps are not accurate enough regarding that class. The highest deviation was present for Grassland, Cropland and Lichens and Mosses classes. Out of the classes for which were labeled with at least "relatively good" score, Forest and Water Permanent have low standard deviation, while for the Water class it is moderate.

## **3.2 HRLC static maps – first production**

Static maps in zoom area for Amazon and Siberia were provided on 23/10/2020. The maps are provided as set of tiles for each region. There is 266 tiles in Amazon and 204 tiles in Siberia. Some of the tiles are partially or completely out of the region of interest. This impacts inter-comparison in some cases because existing datasets were collected based on the region of interest of the project. More in detail, existing dataset were collected within a bounding box which is slightly bigger than the region of interest of the project to take into account possible change of size due to reprojection. However, it did not capture all the tiles included in the static map of Amazon and Siberia. In Figure 3 and Figure 4 it is precisely highlighted for which tiles of static map existing data are not collected for Siberia and Amazonia respectively.

			42XW	и / 4	13XDC	43XE	c \	4	н4хмн	44XNI	4	
			42XW	G	43XDB	43XEE	3		44XMG	44XNG	5 45	5XVB
41)( <mark>N</mark> /	A \ 4	1XPA <sup>42XVF</sup>	42XW	F 42	KXF43XDA			43>	KFA44XMF	44XNF	44XP	F45XVA
41WN		42WVE	42WW	E	43WDV	43WEV			44WME	44WNE	/	45WVV
- 41V/N	ı ∏	42WVD	42WW[		43WDU	43WEU			44WMD	44WND	44W	PD
41WI	41W	PT 42WV0	2 42WWC	: 42WXC	: 43WDT	43WET	43	зфгт	44WMC	44WNC		PC
	41WP	s 42WV	3 42WWB	42WXB	43WDS	43WES	43	wFs	44WME	44WNB	44WPB	45WVS
i	41WPF	42WV	A 42WWA	42WXA	43WDF	R 43WER	43V	VFR	44WM/	44WNA	44WPA	45WVR
	41WPQ	42WVV	42WWV	42WX	V43WDQ	43WEQ	4	13WF0	Q44WMV	44WNV	44WPV	45WVQ
	41WPP	42WVU	42WWU	42WXL	J 43WDP	43WEP	4	зwffp	9 44WMU	44WNU	44WPU	45WVF
41WNN	41WF	N 42WVT	42WWT	42WXT	43WDN	43WEN	43	wFN	44WMT	44WNT	44WPT	45WVI
41WNM	41WP	M 42WVS	42WWS	42WXS	43WDM	43WEM	43	WFM	44WMS	44WNS	44WPS	45WVI
41VNL	42VUF	42VVR	42VWR	43VCL		43VEL	44\	<b>/L</b> R	44VMR	44VNR	45VUL	45 <mark>V</mark> VL
41VNK	42VU(	2 42VVQ	42VWQ	43VCK	43VDK	43VEK	44	VLQ	44 🖂 E	Existing LO	C missing	45VVK
41VNJ	42VU	P 42VVP	42VWP	43VCJ	43VDJ	43VEJ	44	ŧVLP	] ₄ <mark>⊑⊇</mark> 2	Zoom area	Siberia	45VVJ
41VNH 41	VPH	42VVN	42VWN	43	CH43VDH	43VEH 43	FH	44V	'LIN44	Files Siber	ia	H 45VVI
41	VPG -		42VWM		43VDG	43VEG	/ĦG		44VMM	44VNM	45VU	g 45VV

Figure 3. Tiles of static map in zoom area of Siberia

	Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>migh</b> resolution
<b>esa</b>	Issue	Date	Page	and cover
	2.rev.1	01/02/2023	34	CCI

C		20LPM	20LRM 20LQM	211	.TG 21LUG	21LVG	21LWG	21LXG	21LZ 21LYG		LBM 22LCM	22LDM	22LEM	22LFM	22LHM 22LGM	23LK
20	LNL	20LPL	20LRL 20LQL	21L	TF 21LUF	21LVF	21LWF	21LXF	21L2 21LYF	ZF 22	LBL 22LCL	22LDL	22LEL	22LFL	22LHL 22LGL	23LK
20		20LPK	20LRK 20LQK	21L	TE 21LUE		21LWE	21LXE	21L2 21LYE	ZE 22	LBK 22LCK	22LDK		22LFK	22LHK 22LGK	23LK
20	LNJ	20LPJ	20LRJ 20LQJ		TD 21LUD	21LVD	21LWD	21LXD	21L2 21LYD	ZD 221	LBJ 22LCJ		22LEJ	22LFJ	22LHJ 22LGJ	23LK
20			20LRH 20LQH	21L	TC 21LUC	21LVC		21LXC	21L 21LYC	ZC 221	_BH 22LCH		22LEH	22LFH	22LHH 22LGH	23LK
20	KNG	20KPG	20KRG 20KQG	21K	TB 21KUB	21KVB		21KXB	21K 21KYB	ZB 221	квд 22КСG	22KDG		22KFG	22KHG 22KGG	23KK
20		20KPF	20KRF 20KQF	21K	TA 21KUA	21KVA	21KWA		21K 21KYA	ZA 221	(BF 22KCF	22KDF	22KEF	22KFF	22KHF 22KGF	23KK
20		20KPE	20KRE 20KQE	21K	TV 21KUV			21KXV	21K 21KYV	ZV 228	(BE 22KCE	22KDE			22KHE 22KGE	23KK
20		20KPD	20KRD 20KQD	21K		21KVU	21KWU	21KXU	21K 21KYU	ZU 22K	BD 22KCD	22KDD		22KFD	22KHD 22KGD	23KK
20		20KPC	20KRC 20KQC	21K	TT 21KUT		21KWT	21KXT	21k 21KYT	ССТ 22К	:вс 22КСС		22KEC	22KFC	22KHC 22KGC	23 <b>K</b> K
20		20КРВ	20KRB 20KQB	3 216	TS 21KUS		21KWS	21KXS	21H 21KYS	KZS 22K	вв 22КСВ	22KDB		22KFB	22KHB 22KGB	23 <b>K</b> KS
20	KNA		20KRA 20KQA	∖ 21K				21KXR			ва 22кса	22KDA -	22KEA	22KEA	22KHA C missing	2366
20		20KPV	20KQV 20	KRV 1KTQ	21KUQ		21KWQ	21KXQ	21KYQ	21KZQ 22KBV	22KCV	22KDV	Zo	om are es Ama	a Amazon zon	22KHV 23KK
20			20KQU 20	KRU 1KTP	21KUP	21KVP		21KXP	-21KYP	21KZP 22KBU	22KCU	22KDU	22KEU	22KFU		22KHU 23KKP

Figure 4. Tiles of static map in zoom area in Amazon

Inter-comparison results will be shown per tile and per whole region of interest. In case of per-tile results the tiles in which existing data are partially missing will not be considered as they are not comparable to the tiles where existing data are available. On the opposite, results for whole region will take into account also partially covered tiles.

OA<sub>b</sub> was computed for each tile the existing dataset available in a region. Moreover, all error matrices per region were summed up in order to derive error matrix based on which OA<sub>b</sub> was computed for a region as a whole. Please note that with summation of all error matrices in a region some pixels are accounted more than once due to the overlapping of the tiles. Depending on the classification outcome of the overlapping tiles same pixels might have different values. This approach was selected in order to avoid selecting specific mosaicking method that may produce different outcomes with respect to the mosaicking method on the project level that is to be decided in future. Nevertheless, it gives general idea of the agreement of the static maps with existing LC maps in a region.

The results of  $OA_b$  do not take into account binary maps: FNF, GHS BU S1, GSW seasonality, GSW\_v1\_2, AUE.  $OA_b$  for these maps is very high due to the presence of the class that represent all the other classes but the one of interest for the map and therefore can be misleading.

#### 3.2.1 Siberia

#### 3.2.1.1 Overall benchmark accuracy

In Siberia there are 3 existing multiple-class land cover maps with which static product for Siberia region was compared: ESA DUE GlobPermafrost, FROM-GLC and GL30. During inter-comparison it was observed that GL30 contains some classes which are not included in the official product legend. We requested more details about classes from the map producer, however we did not receive reply by the day of conclusion of processing of static products of the first production. Thus, results of inter-comparison with GL30 in Siberia were not reported for the first production.

Γable 24. Overa	l benchmark	accuracy	for who	le Siberia
-----------------	-------------	----------	---------	------------

Existing dataset	OA <sub>b</sub>
ESA DUE GlobPermafrost	46%

	Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>Figh</b> high resolution
<b>esa</b>	Issue	Date Page		and cover
	2.rev.1	01/02/2023	35	cci
	FROM-G	LC	50%	

Given that there are many tiles the results of  $OA_b$  per tile will be displayed in the form of maps of tiles with associated values of  $OA_b$ . There are  $2 OA_b$  maps, one for inter-comparison with FROM GLC (Figure 5) and one with ESA DUE Permafrost (Figure 6). Some of the tiles have more than one value displayed. The second value is for the tile that is underneath the displayed one. For most of the tiles the  $OA_b$  values for overlapping tiles is similar.

											N
			97%	6	97%	100	26	99%	97%	3	/ \
	86%				97%	98%		85%	30%	5	24%
	87	%87%	19%	7	3%74%	7 76%	Δ	<sup>60%</sup> 63%	21%	8	<b>%10%</b>
	68%	61%	13%	47	% 47%	53%		20% 18%	40%	99	8 119%
	55	% 39%	16%	54%	<sup>6</sup> 53%	18%		19% 17%	32%	12	<b>%</b>
	68%	45%	29%	50%	48%	13%	14	<sup>96</sup> 12%	17%	169	6
	62%	70%	28%	53%	65%	41%	179	<sup>6</sup> 13%	12%	20%	25%
	17%	24%	22%	49%	62%	23%	24%	149%	13%	20%	40%
	21%	18%	28%	71%	50%	20%	21%	20%	26%	42%	56%
	47%	30%	38%	40%	20%	22%	29%	22%	37%	57%	67%
	44%	35%	29%	31%	32%	26%	36%	38%	48%	70%	59%
	58%	54%	47%	33%	30%	32%	35%	48%	65%	68%	70%
72	2%72%	68%	51%	<sup>44%</sup> 44%	42%	41%	39% 39	% 56%	64%	67% <sub>67%</sub>	69%
79	% 80%	71%	41%	46% 46%	40%	32%	32% 33	% 47%	57%	60% 62%	74%
789	% 74%	69%	56%	47% 47%	45%	56%	72% 70	9% 52%	49%	57% 62%	90%
61%	<sup>%</sup> 61%	62%	61%	52% 63%	67%	62%	57% 5	65%	77%	77% 74%	74%
60%	6 54%	55%	68%	3% 64%	69%	72%	59% 6	2% 51%	68%	64%	59%
					OA	<sub>b</sub> range					
0		150		300 km	-	8 - 20 %	20 -	40 % 🛄 40 -	- 60 % 🔲	60 - 80 % 📕	80 - 100%

Figure 5.  $OA_{\mbox{\tiny b}}$  for each tile of static map in Siberia based on FROM GLC

The ESA DUE Permafrost size is smaller than the zoom area in Siberia therefore the appearance of the map is different with respect to the previous map.
	Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>migh</b> resolution
<b>esa</b>	Issue	Date	Page	and cover
	2.rev.1	01/02/2023	36	

Γ

											N
		84%	9	3%	95%	5		88%			
9	4%94%	44%	809	<sup>%</sup> 80%	77%		6	<sup>7%</sup> 70%	7		
75	% 71%	31%	53%	52%	57%		289	% 22%			
56%	<sub>6</sub> 47%	22%	59%	58%	29%		31%	30%			
72%	54%	36%	62%	62%	26%		18%	18%			
69%	74%	29%	66%	77%	51%		19%	12%			
34%	39%	40%	58%	73%	28%	4	7%	22%			
40%	41%	32%	82%	65%	22%	4	2%	46%			
48%	43%	64%	59%	39%	33%	44	%	66%			
35%	26%	45%	35%	37%	40%	4	10%	41%			
26%	19%	37%	34%	36%	37%	4	3%	48%			
23%23%	29%	34%	40% 40%	38%	41%	45%	45%	42%			
28% 27%	27%	39%	43% 42%	39%	35%	35%	34%	32%			
33% 35%	28%	32%	37% 39%	32%	28%	29%	31%	36%			
33% 33%	38%	35%	31% 30%	25%	32%	29%	30%	36%			
				OA <sub>b</sub> ra	ange						
	150		300 km	12	- 20 % 📃	20 - 4	10 % [	<mark> 40</mark> - 60 %	60 - 80 %	80 -	95%

Figure 6.  $OA_b$  for each tile of static map in Siberia based on ESA DUE Permafrost

	Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>migh</b> resolution
<b>esa</b>	Issue	Date	Page	and cover
	2.rev.1	01/02/2023	37	CCI

# 3.2.1.2 Per class benchmark accuracy

## Table 25. UA<sub>b</sub> and PA<sub>b</sub> for whole Siberia

Existing LC	Index	Bareland	Built-up	Cropland	Forest	Forest deciduous broadleaf	Forest evergreen needleleaf	Grassland	Lichens and Mosses	Permanent ice and snow	Shrubland	Shrubland evergreen	Water	Water permanent	Water seasonal	Wetland
ESA DUE GlobPermafrost		32%				39%	1%	48%	16%			23%		92%	44%	46%
FROM-GLC		41%	53%	0%	87%			19%	7%	0%	15%		97%			50%
FNF	DA.				83%								90%			
GHS BU S1	PAb		54%													
GSW seasonality														86%	26%	
GSW_v1_2														88%	24%	
ESA DUE GlobPermafrost		25%				21%	17%	20%	10%			74%		99%	37%	7%
FROM-GLC		5%	11%	0%	77%			43%	64%	0%	0%		91%			6%
FNF	114.				67%								83%			
GHS BU S1	UAb		9%													
GSW seasonality														96%	19%	
GSW_v1_2														52%	17%	

	Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>Figh</b> resolution
<b>esa</b>	Issue	Date	Page	and cover
	2.rev.1	01/02/2023	38	cci

## 3.2.2 Amazon

### 3.2.2.1 Overall benchmark accuracy

In Amazon there are 3 existing multiple-class land cover maps with which static product for Amazon region was compared: FROM-GLC, GL30 and MapBiomas. Table 26 is showing the consistency between static map in Amazon and each of the existing land cover maps.

Existing dataset	OA <sub>b</sub>
FROM-GLC	62%
GL30	48%
MapBiomas	62%

As in the case of Siberia, also for Amazon results of  $OA_b$  will be shown in form of maps for  $OA_b$  with each of the three existing land cover available in the region.  $OA_b$  with respect to FROM-GLC is shown in Figure 7, with respect to GL30 Figure 8 in and with respect to MapBiomas in Figure 9.

69%	869 80%	% 89	9% 83%	88%	82%	82%	929 84%	% 91	% 86%	64%	58%	55%	45 50%	% 499
72%	83% 71%	81	% 72%	83%	82%	84%	79' 73%	% 76	% 72%	68%	64%	55%	46 52%	% 469
94%	739 83%	% 70	)% 65%	74%	73%	70%	48 66%	% 56	% 54%	68%	61%	49%	41 51%	% 38%
96%	679 80%	% 62	59%	69%	55%	58%	64 65%	% 59	% 56%	68%	54%	51%	47 48%	% 47%
83%	62%	% 63	% 66%	62%	60%	68%	60 58%	% 57	% 56%	55%	52%	55%	50 52%	% 50%
81%	839 80%	% 74	% 67%	52%	62%	63%	57 61%	% 56	% 53%	54%	58%	54%	58 62%	8% 58%
41%	919 63%	% 94	% 85%	60%	61%	61%	64 70%	% 60	% 66%	72%	71%	64%	60 59%	)% 58%
149%	79 56%	% 88	% 85%	66%	64%	71%	71 65%	.% 65'	% 67%	55%	61%	59%	61%	L% 57%
5%	73 48%	% 76	% 84%	63%	64%	68%	76 69%	5% 779	% 70%	61%	60%	51%	63%	5% 65%
18%	23%	45	% 60%	57%	71%	60%	68%	749	% 73%	70%	64%	58%	74%	61%
23%	32%	47	% 39%	56%	68%	67%	68%	749	% 70%	60%	62%	59%	64%	59%
33%	50%	48%	60%	60%	62%	68%	68%	67%	75%	60%	58%	63%	62%	59%
30%	56%	46%	51%	57%	59%	69%	69%	61%	59%	68%	70%	69%	65%	58%
39%	68%	47%	45%	49%	52%	61%	68%	63%	69%	62%	66%	71%	76%	81%
	2	50		500 k	O. m	A <sub>b</sub> ran	ge 20 % 📘	20 - 4	0 % 🗌	]40 - 6(	) %	] <mark>60 - 8</mark> (	0 % 🔲	80 - <mark>9</mark> 9 %

Figure 7.  $OA_{\mbox{\tiny b}}$  for each tile of static map in Amazon based on FROM GLC

	Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>Figh</b> resolution
<b>C</b> esa	Issue	Date	Page	and cover
	2.rev.1	01/02/2023	39	CCI

64%	73%	65%	52%	74%	74%	74%	75%		77%	75%	35%	17%	20%	23%	31%
60%	62%	59%	53%	66%	71%	74%	63%		57%	58%	22%	21%	14%	25%	36%
92%	73%	62%	61%	50%	49%	55%	40%		26%	33%	25%	18%	27%	36%	33%
95%	75%	46%	34%	42%	33%	33%	47%		30%	33%	19%	24%	36%	36%	37%
78%	54%	32%	27%	40%	33%	39%	37%		33%	30%	20%	24%	30%	31%	41%
82%	, 79%	52%	32%	33%	31%	26%	33%		35%	30%	33%	37%	34%	42%	48%
48%	62%	90%	79%	49%	42%	37%	38%		39%	49%	65%	65%	51%	34%	47%
91%	68%	87%	81%	49%	24%	28%	28%		39%	42%	30%	47%	59%	44%	35%
89%	80%	76%	74%	36%	24%	24%	39%		16%	19%	25%	39%	36%	41%	49%
60%	69%	52%	51%	35%	41%	33%	32%		12%	111%	33%	33%	43%	67%	46%
53%	36%	49%	55%	46%	41%	54%	49%		18%	21%	34%	44%	47%	58%	48%
44%	34%	48%	71%	50%	41%	62%	54%		33%	36%	35%	44%	37%	47%	47%
49%	45%	51%	54%	47%	47%	48%	39%		30%	44%	64%	63%	51%	54%	48%
74%	67%	54%	48%	42%	42%	46%	49%	T	45%	62%	51%	51%	54%	65%	78%
					. (	OA <sub>b</sub> ra	nge								
		250		500	km	11	- 20 %		20 - 4	10 % 🗌	40 -	60 % 🗌	60 - 8	30 %	80 - 99

Figure 8.  $OA_{\mbox{\tiny b}}$  for each tile of static map in Amazon based on GL30

The MapBiomas dataset does not completely cover zoom area in Amazon therefore the appearance of the map is different with respect to the previous two maps for Amazonia.

70% 75% 66	% 73%	87%	81%	82%	959 84%	6 96	% 86%	62%	63%	48%	46% 50%	53%
82% 68% 54 72%	% 61%	80%	80%	81%	79% 72%	6 75'	% 69%	64%	63%	51%	53% 51%	52%
77% 63 <sup>4</sup>	% 68%	64%	70%	63%	399	<sup>76</sup> 43'	% 46%	68%	61%	45%	54% 53%	53%
66% 57% 55°	% 50%	62%	49%	49%	569 62%	6 519	% 56%	70%	56%	49%	53% 49%	55%
42% 46% 559	% 63%	59%	54%	62%	509 52%	% 48°	% 54%	60%	56%	58%	57% 55%	56%
36% 56% 559	% 66%	57%	64%	56%	519 53%	% 53°	% 55%	55%	61%	60%	61% 62%	63%
	60%	61%	64%	60%	579 61%	% 579	% 62%	70%	71%	63%	62% 57%	62%
10 10		53%	61%	72%	63' 59%	% 639	% 65%	53%	59%	53%	62% 57%	59%
	87%	57%	62%	67%	69 67%	% 719	67%	59%	57%	44%	64% 58%	64%
	62%	48%	64%	59%	67%	709	% 71%	68%	57%	43%	57%	58%
	43%	48%	65%	68%	68%	729	% 70%	57%	56%	49%	41%	52%
	50%	51%	63%	72%	65%	62%	75%	57%	54%	60%	58%	53%
, L				72%	66%	57%	58%	68%	68%	66%	65%	51%
				58%	65%	62%	69%	59%	65%	70%	75%	77%
252					0	A <sub>b</sub> ran	ge					

Figure 9. OA<sub>b</sub> for each tile of static map in Amazon based on MapBiomas

	Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>migh</b> resolution
<b>esa</b>	Issue	Date	Page	and cover
	2.rev.1	01/02/2023	40	CCI

# 3.2.2.2 Per class benchmark accuracy

### Table 27. UA<sub>b</sub> and PA<sub>b</sub> for whole Amazon

Dataset	Index	Bareland	Built-up	Cropland	Forest	Grassland	Shrubland	Water	Water permanent	Water seasonal	Wetland	Wetland Herbaceous	Wetland Shrubby
FROM GLC		53%	53%	68%	91%	54%	19%	80%			55%		
GL30		14%	43%	34%	88%	43%	17%	75%			17%		
MapBiomas		36%	59%	65%	88%	59%	21%	74%				40%	0%
FNF	DA				84%			26%					
GHS BU S1	FA		59%										
AUE*			80%					28%					
GSW seasonality									83%	15%			
GSW v1 2									87%	12%			
FROM GLC		0%	36%	67%	69%	74%	25%	67%			19%		
GL30	1	0%	38%	90%	65%	15%	22%	67%			38%		
MapBiomas		3%	48%	69%	67%	79%	20%	76%				27%	0%
FNF	UA				68%			52%					
GHS BU S1			26%										
AUE*			54%					38%					
GSW seasonality									76%	12%			
GSW v1 2									74%	21%			

\*AUE covers only partially 4 tiles out of 266 in Amazon.

Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>migh</b> resolution
Issue	Date	Page	and cover
2.rev.1	01/02/2023	41	CCI

## 3.2.3 Africa

### 3.2.3.1 Overall benchmark accuracy

In Africa there are 2 existing multiple-class land cover maps with which static product for African region were compared: FROM-GLC and GL30. Table 28 is showing the consistency between static map in Africa and each of the existing land cover maps.

Existing dataset	OA <sub>b</sub>
FROM-GLC	44%
GL30	33%

Results of  $OA_b$  will be shown in form of maps for  $OA_b$  with each of the two existing land cover available in the region.  $OA_b$  with respect to FROM-GLC is shown in Figure 10, with respect to GL30 in Figure 11.

	65%	65%	64%	49%	50%	54%	34%	21%	13%	17%	29%	24%	° 27%	35%	52%	91%	98%	· '	
9776 8	10%	9%	6%	1493	12%	9%	27%	33%	45%	66%	72%	51%	<sup>6</sup> 32%	36%	43%	76%	77%	92%	
978	29%	2%	6%	8%	8%	8%	23%	67%	64%	56%	49%	339	<sup>%</sup> 32%	35%	43%	69%	70%	57% 78%	6
978	093	8%	25%	40%	37%	° 43%	29%	80%	66%	36%	33%	43%	<sup>%</sup> 59%	34%	33%	51%	64%	55% 56%	<sup>8</sup> 95%
976 S	1193	28%	39%	42%	38%	6 42%	34%	67%	55%	41%	30%	34%	50%	35%	30%	48%	63%	78% 769	6 95%
9%	41%	55%	48%	40%	38%	<sup>9</sup> 31%	38%	32%	40%	31%	28%	349	<sup>6</sup> 50%	45%	36%	32%	48%	69% 709	<sup>6</sup> 73%
9%	48%	38%	38%	35	%39%	41%	33%	18%	33%	32%	33	%36%	38%	37%	41%	39%	41%	52%49%	48%
2% 3	36%	48%	40%	44	%43%	39%	35%	37%	36%	48%	45	%41%	40%	47%	49%	45%	57%	67%67%	59%
9% 5	51%	53%	49%	379	%37%	37%	44%	43%	46%	54%	42	%35%	27%	43%	50%	48%	49%	64%63%	64%
5%	45%	61%	45%	440	%41%	41%	53%	39%	51%	46%	39	%32%	33%	33%	37%	38%	52%	52%47%	49%
0%	43%	40%	37%	560	% 54%	52%	59%	50%	45%	34%	31	% 27%	32%	18%	28%	21%	44%	43% 55%	56%
0% 5	59%	43%	52%	470	% 50%	53%	46%	45%	40%	26%	32	% 23%	16%	31%	21%	42%	51%	51% 55%	44%
e	64%	64%	52%	539	% 46%	45%	40%	40%	30%	27%	54	% 28%	22%	30%	30%	43%	66%	51% 47%	54%
5% 4 0% 4 0% 5	45% 43% 59%	61% 40% 43%	45% 37% 52% 52%	44° 56° 47°	<ul> <li>6 51%</li> <li>6 54%</li> <li>6 50%</li> <li>6 46%</li> </ul>	41% 52% 53% 45%	53% 59% 46%	39% 50% 45%	10% 51% 45% 40% 30%	46% 34% 26% 27%	39 <sup>1</sup> 31 <sup>1</sup> 32 <sup>0</sup> 54 <sup>0</sup>	% 32% % 27% % 23%	27% 33% 32% 16% 22%	33% 18% 31% 30%	37% 28% 21% 30%	38% 21% 42%	52% 44% 51% 66%	52%47% 43%55% 51%55%	

Figure 10. OA<sub>b</sub> for each tile of static map in Africa based on FROM GLC

	Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>migh</b> resolution
<b>esa</b>	Issue	Date	Page	and cover
	2.rev.1	01/02/2023	42	cci



Figure 11.  $OA_b$  for each tile of static map in Africa based on GL30

## 3.2.3.2 Per class benchmark accuracy

Dataset	Index	Bareland	Built-up	Cropland	Forest	Grassland	Shrubland	Water	Water permanent	Water seasonal	Wetland
FROM GLC		85%	12%	46%	70%	19%	44%	84%			8%
GL30		83%	20%	36%	36%	18%	38%	87%			21%
GHS BU S1			28%								
WSF	PA		31%								
FNF					35%			87%			
GSW seasonality									90%	63%	
GSW v1 2									91%	51%	
FROM GLC		48%	1%	43%	19%	34%	56%	92%			1%
GL30		43%	3%	43%	42%	50%	15%	61%			9%
GHS BU S1			1%								
WSF	UA		5%								
FNF					76%			84%			
GSW seasonality									99%	19%	
GSW v1 2									76%	32%	

### 3.2.4 Conclusions

Overall agreement of the static map with existing land cover maps in Siberia is around 50% (Table 24). The highest agreement is in the northern parts of zoom area due to the dominance of water class which is generally well classified (Figure 5 and Figure 6). Agreement is slightly larger with FROM-GLC then with ESA DUE Permafrost.

	Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>migh</b> resolution
<b>esa</b>	Issue	Date	Page	and cover
	2.rev.1	01/02/2023	43	cci

Regarding individual accuracy indexes the classification are interpreted as "excellent" if both scores  $PA_b$  and  $UA_b$  (in the) are above 90%, "well" if the scores are between 70% and 90% and "relatively good" if the scores are between 50% and 70% (For Siberia according to the Table 25 classification of Forest class is relatively good, while for Water and Water permanent class it varies from relatively good to excellent, depending on the existing dataset with which static map is compared with. For other classes the results are low or not possible to interpret.

Agreement of static map in Amazon with existing land cover maps in that region shows higher agreement than in Siberia. OA<sub>b</sub> in Amazon is 62% with respect to FROM-GLC and MapBiomas LC, while with respect to GL30 it is 48%. There is couple of patches of tiles where agreement with FROM-GLC (Figure 7) and MapBiomas (Figure 9) exceeds 80%. Visual inspection or these patches showed that it is most probably associated with relatively homogeneous forest landscape. Agreement with GL30 (Figure 8) is generally lower compared to agreement with other two maps in Amazon. Class-wise agreement with existing maps was analysed based on FROM-GLC and MapBiomas because results of inter-comparison with them are similar (Table 27). In case of Permanent water, relatively well to good in case of Water and Forest and relatively well in case of Cropland and Grassland.

According to the AUE dataset Built-up class is relatively well classified, which is not evident from other datasets. Given that AUE dataset is focused on big cities (Ribeirao Preto and partially Sao Paolo) it may indicate that classification of built-up class is more successful in cities with respect to built-up elsewhere. It might be affected by homogeneity of built up class in cities.

For static map in Africa the agreement with existing HRLC is lower than with respect to other two regions.  $OA_b$  with respect to FROM-GLC is 44%, and 33% with GL30 (Table 28).  $UA_b$  and  $PA_b$  (Table 29) are indicating that the Forest class is not classified as good as in Amazon or Siberia, and probably this is the reason behind low overall agreement. Water permanent class has excellent agreement, while the agreement with Water is well. Visual inspection of  $OA_b$  for each tile of static map for GL30 and FROM-GLC (Figure 10, Figure 11) do not show any meaningful patterns.

For further conclusions based on inter-comparison it would be important to have information about reliability of the existing products in the regions of interest for the project. The reliability of existing products could be estimated using the validation dataset of the project.

# **3.3 HRLC historical maps – first production**

Historical maps in zoom area for Amazon were provided on 28/12/2020, for Siberia on 15/01/2021, and for Africa on 18/03/2021. Table 30 contains details about the number of tiles per each region and each historical product available so far.

Year	Region	Number of tiles	Region	Number of tiles	Region	Number of tiles
2015	Amazon	266	Siberia	212	Africa	291
2010	Amazon	266	Siberia	215	Africa	290
2005	Amazon	266	Siberia	215	Africa	291
2000	Amazon	263	Siberia	213	Africa	291
1995	Amazon	266	Siberia	205	Africa	279
1990	Amazon	262	Siberia	208	Africa	273

### 3.3.1 Amazon 2015

Following existing land cover maps are used for inter-comparison of historical products for 2015:

- FROM GLC 2015
- MapBiomas 2015



- TerraClass 2014
- GHS BU LDS 2014
- WSF 2015
- FNF 2015
- GSW seasonality 2015
- GSW v1 2 2015
- AUE 2014 (Sao Paolo), 2014 (Ribeirao Preto)

### 3.3.1.1 Overall benchmark accuracy

There are 3 existing multiple-class land cover maps for year 2015 with which historical product for Amazon region was compared: FROM-GLC, TerraClass and MapBiomas. Table 31 is showing the consistency between historical map in Amazon and each of the existing land cover maps.

Existing dataset	OA <sub>b</sub>
FROM-GLC	57%
MapBiomas	57%
TerraClass	63%

Amazon results of  $OA_b$  will be shown in form of maps for  $OA_b$  with each of the three existing land cover available in the region.  $OA_b$  with respect to FROM-GLC is shown in Figure 12, with respect to MapBiomas Figure 13 in and with respect to TerraClass in Figure 14.



#### Figure 12. OA<sub>b</sub> for each tile of 2015 historical map in Amazon based on FROM GLC

The MapBiomas dataset does not completely cover zoom area in Amazon therefore the appearance of the map is different with respect to the FROM-GLC map for Amazonia.

	Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>Figh</b> resolution
<b>esa</b>	Issue	Date	Page	and cover
	2.rev.1	01/02/2023	45	CCI



Figure 13. OA<sub>b</sub> for each tile of 2015 historical map in Amazon based on MapBiomas

The TerraClass dataset covers only small portion of the zoom area in Amazon therefore the appearance of the map is different with respect to the previous two maps for Amazonia.



Figure 14. OA<sub>b</sub> for each tile of 2015 historical map in Amazon based on TerraClass

	Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>migh</b> resolution
esa	Issue	Date	Page	and cover
	2.rev.1	01/02/2023	46	CCI

# 3.3.1.2 Per class benchmark accuracy

### Table 32. UA<sub>b</sub> and PA<sub>b</sub> for whole 2015 Amazon

Dataset	Index	Bareland	Built-up	Cropland	Forest	Grassland	Shrubland	Water	Water permanent	Water seasonal	Wetland	Wetland Herbaceous
FROM GLC		48%	75%	53%	91%	44%	7%	90%			19%	
MapBiomas		52%	73%	51%	92%	54%	11%	85%				20%
TerraClass		7%	1%	36%	95%	47%	5%	62%				
GHS BU LDS			83%					96%				
WSF			69%									
FNF					85%			35%				
GSW seasonality									87%	33%		
GSW v1 2									90%	30%		
FROM GLC		0%	30%	52%	67%	66%	18%	67%			12%	
MapBiomas		1%	54%	41%	65%	77%	25%	76%				36%
TerraClass		1%	31%	34%	74%	66%	13%	62%				
GHS BU LDS			27%					40%				
WSF	UA		36%									
FNF					67%			57%				
GSW seasonality									82%	14%		
GSW v1 2									80%	29%		
AUE Ribeirao Preto	DA		70%					42%				
AUE Sao Paulo	PA		66%					85%				
AUE Ribeirao Preto			77%					30%				
AUE Sao Paulo	UA		79%					46%				

	Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>mage</b> high resolution
<b>esa</b>	Issue	Date	Page	and cover
	2.rev.1	01/02/2023	47	CCI

### 3.3.2 Amazon 2010

Following existing land cover maps are used for inter-comparison of historical products for 2010:

- FROM GLC 2010
- GL30 2010
- MapBiomas 2010
- TerraClass 2010
- GUF 2011
- FNF 2010
- GSW seasonality 2010
- GSW v1 2 2010

### 3.3.2.1 Overall benchmark accuracy

There are 4 existing multiple-class land cover maps for year 2010 with which historical product for Amazon region was compared: FROM-GLC, GL30, TerraClass and MapBiomas. Table 33 is showing the consistency between historical map in Amazon and each of the existing land cover maps.

Table 33. Overall benchi	mark accuracy for	r whole Amazon	in 2010
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Existing dataset	OA <sub>b</sub>
FROM-GLC	46%
GL30	44%
MapBiomas	51%
TerraClass	67%

Amazon results of  $OA_b$  will be shown in form of maps for  $OA_b$  with each of the four existing land cover available in the region.  $OA_b$  with respect to FROM-GLC is shown in Figure 15, with respect to GL30 Figure 16, with respect to MapBiomas Figure 17 and with respect in and with respect to TerraClass in Figure 18

71%	52%	68% <sup>78</sup>	3% 74	<sup>%</sup> 67%	81%	70%	71%	82% <sup>89</sup>	87	<sup>%</sup> 72%	36%	28%	36%	45% 30%	6 23%
75%	69%	65%	5% 65	<sup>%</sup> 61%	77%	73%	72%	81% 77	% 70	<sup>%</sup> 56%	32%	37%	39%	40% 30%	6 24%
84%	91%	75%	1% 57	<sup>%</sup> 48%	63%	68%	59%	47% 28	% 31	<sup>%</sup> 43%	43%	34%	36%	41% 30%	6 25%
89%	88%	66% 5	7% 51	<sup>%</sup> 44%	61%	51%	48%	52% 49	% 43'	<sup>%</sup> 43%	42%	29%	34%	34% <sup>329</sup>	% 31%
77%	64%	48%	4% 40	<sup>%</sup> 43%	61%	52%	55%	45% <sup>36</sup>	% 30'	<sup>%</sup> 31%	34%	25%	25%	29% 33	% 34%
44%	50%	61% <sup>5</sup>	7% 60	<sup>%</sup> 49%	50%	50%	54%	53% 43	% 42	<sup>%</sup> 36%	34%	29%	28%	46% 489	% 45%
30%	35%	51% <sup>8</sup>	9% 93	<sup>%</sup> 71%	45%	56%	62%	53% 46	% 44	<sup>%</sup> 44%	42%	42%	43%	45% 45	% 45%
33%	41%	51%	6% 61	<sup>%</sup> 82%	45%	45%	57%	45%	5% 459	<sup>%</sup> 52%	38%	42%	40%	43% 42	% 39%
10%	36%	37% 5	6% 64	<sup>%</sup> 69%	38%	37%	44%	50% 50	0% 47°	49%	38%	42%	34%	39% 44	% 39%
39%	49%	21%	2% 53	63%	30%	43%	43%	45% 5	1% 499	50%	43%	34%	32%	35% 32	% 31%
4936	17%	26%	43% 40%	61%	53%	45%	43%	42%	43% 42%	50%	36%	38%	36%	30%	38% 35%
23%	25%	21%	29% 31%	62%	56%	44%	43%	39%	31% 35%	49%	35%	41%	41%	37%	35% 34%
5%	1993	35%	30% 33%	65%	60%	49%	50%	43%	42% 41%	40%	42%	39%	39%	43%	36% 37%
13%	29%	55%	43% 44%	45%	42%	42%	50%	42%	41% 40%	42%	26%	39%	41%	51%	63% 65%
		250		500	km	OAb	FROM	-GLC 2	010	20 -	40 %	6	0 - 80	% 🗾 8	30 - 93 9

Figure 15. OA<sub>b</sub> for each tile of 2010 historical map in Amazon based on FROM GLC

<b>A</b> 62 <b>A</b>	Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>Figh</b> resolution
<b>esa</b>	Issue	Date	Page	and cover
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72%	64%	71% 73	3% 64	<sup>%</sup> 54%	75%	64%	67%	76% 75	% 76	<sup>%</sup> 72%	31%	15%	30%	28%	19%
69%	57%	65% <sup>67</sup>	7% 57	<sup>%</sup> 55%	67%	65%	68%	76% 64	% 59	54%	19%	28%	28%	30%	25%
81%	92%	72% 52	2% 52	43%	50%	52%	51%	39%23	% 22	<sup>%</sup> 36%	27%	25%	32%	35%	22%
95%	91%	62% <sup>35</sup>	5% 36	<sup>%</sup> 27%	41%	30%	35%	48% 44	% 35	<sup>%</sup> 36%	27%	28%	36%	35%	26%
80%	79%	50% 36	6% 29	<sup>%</sup> 28%	40%	30%	39%	36% 28	% 27	<sup>%</sup> 32%	24%	27%	28%	33%	28%
55%	85%	83% <sup>60</sup>	8% 52	<sup>%</sup> 36%	50%	30%	22%	35% <sup>35</sup>	% 31	<sup>%</sup> 32%	33%	31%	31%	38%	36%
39%	62%	72% 9	0% 89	<sup>%</sup> 71%	67%	40%	35%	40% 34	1% 36	<sup>%</sup> 40%	48%	48%	44%	29%	28%
48%	60%	64% <sup>8</sup>	5% 94	<sup>76</sup> 85%	62%	27%	23%	38% 30	0% 32	<sup>%</sup> 38%	38%	44%	55%	41%	40%
38%	78%	57% 8	4% 819	<sup>%</sup> 62%	30%	26%	29%	44% 3	2% 26	<sup>%</sup> 30%	34%	46%	40%	40%	45%
1473	39%	29% 3	9% 47	62%	24%	37%	33%	40% <sup>2</sup>	3% 27	<sup>%</sup> 25%	44%	28%	41%	55%	58%
30%	29%	20%	44% 38%	46%	38%	38%	41%	39%	29% 31%	39%	26%	35%	39%	39%	37%
47%	42%	26%	33% 37%	53%	45%	31%	45%	39%	28% 30%	35%	25%	31%	28%	35%	31%
36%	52%	52%	48% 49%	59%	44%	40%	44%	37%	30% 26%	36%	40%	39%	37%	41%	37%
33%	61%	69%	51% 48%	40%	39%	38%	41%	42%	35% 34%	40%	27%	34%	34%	46%	47%
		250		500	km	c	DAb G	L <b>30 20</b>	10	20 - 4   40 - 6	0 %	60	- 80 %	5 <b></b> - 8	30 - 95

Figure 16.  $OA_b$  for each tile of 2010 historical map in Amazon based on GL30

The MapBiomas dataset does not completely cover zoom area in Amazon therefore the appearance of the map is different with respect to the previously displayed maps for Amazonia.



Figure 17.  $OA_{b}\xspace$  for each tile of 2010 historical map in Amazon based on MapBiomas

The TerraClass dataset covers only small portion of the zoom area in Amazon therefore the appearance of the map is different with respect to the previous three maps for Amazonia.

	Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>Figh</b> resolution
<b>esa</b>	lssue	Date	Page	and cover
	2.rev.1	01/02/2023	49	



Figure 18. OA<sub>b</sub> for each tile of 2010 historical map in Amazon based on TerraClass

Cesa	Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>mage</b> high resolution
	Issue	Date	Page	and cover
	2.rev.1	01/02/2023	50	CCI

# 3.3.2.2 Per class benchmark accuracy

### Table 34. UA<sub>b</sub> and PA<sub>b</sub> for whole 2010 Amazon

Dataset	Index	Bareland	Built-up	Cropland	Forest	Grassland	Shrubland	Water	Water permanent	Water seasonal	Wetland	Wetland Herbaceous	Wetland Shrubby
FROM GLC		12%	55%	42%	70%	36%	4%	44%					
GL30		22%	58%	35%	78%	34%	6%	79%					
MapBiomas		43%	75%	58%	81%	45%	9%	77%				65%	0%
TerraClass	ПА	10%	36%	60%	92%	51%	9%	10%					
GUF	PA		75%										
FNF					77%			20%					
GSW seasonality									85%	15%	55%		
GSW v1 2									88%	14%	4%		
FROM GLC		1%	4%	43%	68%	51%	7%	28%					
GL30		0%	11%	67%	66%	16%	17%	29%					
MapBiomas		1%	19%	38%	62%	82%	18%	32%				16%	0%
TerraClass		0%	10%	55%	77%	77%	12%	40%					
GUF	UA		14%								27%		
FNF	]				71%			2%			33%		
GSW seasonality	]								38%	3%			
GSW v1 2	]								37%	5%			

	Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>Figh</b> resolution
<b>esa</b>	Issue	Date	Page	and cover
	2.rev.1	01/02/2023	51	cci

### 3.3.3 Amazon 2005

Following existing land cover maps are used for inter-comparison of historical products for 2005:

- MapBiomas 2005
- TerraClass 2004
- FNF 2007
- GSW seasonality 2005
- GSW v1 2 2005

#### 3.3.3.1 Overall benchmark accuracy

There are 2 existing multiple-class land cover maps for year 2005 with which historical product for Amazon region was compared: TerraClass and MapBiomas. Table 35 is showing the consistency between historical map in Amazon and each of the existing land cover maps.

Table 35. Overall benchmark accuracy for whole Amazon in 2005

Existing dataset	OA <sub>b</sub>
MapBiomas	55%
TerraClass	75%

Amazon results of  $OA_b$  will be shown in form of maps for  $OA_b$  with each of existing land cover available in the region.  $OA_b$  with respect to MapBiomas is shown in Figure 19, and with respect to TerraClass in Figure 20. As it can be seen from the figures none of the available land cover is as large as the zoom area.



Figure 19. OA<sub>b</sub> for each tile of 2005 historical map in Amazon based on MapBiomas

	Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>migh</b> resolution
<b>esa</b>	Issue	Date	Page	and cover
	2.rev.1	01/02/2023	52	CCI



Figure 20. OA<sub>b</sub> for each tile of 2005 historical map in Amazon based on TerraClass

629	Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>mage</b> high resolution
<b>esa</b>	Issue	Date	Page	and cover
	2.rev.1	01/02/2023	53	CCI

# 3.3.3.2 Per class benchmark accuracy

### Table 36. UA<sub>b</sub> and PA<sub>b</sub> for whole 2005 Amazon

Dataset	Index	Bareland	Built-up	Cropland	Forest	Grassland	Shrubland	Water	Water permanent	Water seasonal	Wetland Herbaceous	Wetland Shrubby
MapBiomas		39%	71%	58%	85%	53%	11%	72%			61%	0%
TerraClass		6%	2%	56%	92%	54%	9%	68%				
FNF	PA				80%			38%				
GSW seasonality									80%	15%		
GSW v1 2									84%	14%		
MapBiomas		1%	27%	41%	68%	78%	17%	46%			14%	0%
TerraClass		0%	12%	38%	86%	75%	7%	50%				
FNF	UA				74%			31%				
GSW seasonality									63%	3%		
GSW v1 2									61%	6%		

	Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>mage</b> high resolution
<b>esa</b>	Issue	Date	Page	and cover
	2.rev.1	01/02/2023	54	CCI

### 3.3.4 Amazon 2000

Following existing land cover maps are used for inter-comparison of historical products for 2000:

- MapBiomas 2000
- GL30 2000
- GHS BU LDS 2000
- TreeCover 2000
- GSW seasonality 2000
- GSW v1 2 2000
- AUE 2000 (Sao Paolo), 2001 (Ribeirao Preto)

#### 3.3.4.1 Overall benchmark accuracy

There are 2 existing multiple-class land cover maps for year 2000 with which historical product for Amazon region was compared: GL30 and MapBiomas. Table 37 is showing the consistency between historical map in Amazon and each of the existing land cover maps.

Table 37. Overall benchmark accuracy f	for whole Amazon in 2000
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Existing dataset	OA <sub>b</sub>
GL30	43%
MapBiomas	50%

Amazon results of  $OA_b$  will be shown in form of maps for  $OA_b$  with each of the four existing land cover available in the region.  $OA_b$  with respect to GL30 is shown in Figure 21, and with respect to MapBiomas in Figure 22.



Figure 21.  $OA_b$  for each tile of 2000 historical map in Amazon based on GL30

The MapBiomas dataset does not completely cover zoom area in Amazon therefore the appearance of the map is different with respect to the GL30 map for Amazonia.

	Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>Figh</b> resolution
<b>esa</b>	lssue	Date	Page	and cover
	2.rev.1	01/02/2023	55	



Figure 22. OA<sub>b</sub> for each tile of 2000historical map in Amazon based on MapBiomas

esa	Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>migh</b> resolution
<b>esa</b>	Issue	Date	Page	and cover
	2.rev.1	01/02/2023	56	CCI

# 3.3.4.2 Per class benchmark accuracy

### Table 38. UA<sub>b</sub> and PA<sub>b</sub> for whole 2000 Amazon

Dataset	Index	Bareland	Built-up	Cropland	Forest	Grassland	Shrubland	Water	Water permanent	Water seasonal	Wetland	Wetland Herbaceous	Wetland Shrubby
MapBiomas		52%	64%	39%	86%	48%	6%	73%				72%	0%
GL30		26%	48%	28%	82%	38%	5%	69%			28%		
GHS BU LDS	DA		65%					92%					
TreeCover	PA				86%								
GSW seasonality									74%	21%			
GSW v1 2									76%	17%			
MapBiomas		1%	13%	27%	64%	78%	15%	36%				14%	0%
GL30		0%	9%	76%	63%	16%	17%	36%			26%		
GHS BU LDS	114		8%					21%					
TreeCover	UA				82%								
GSW seasonality									43%	4%			
GSW v1 2									42%	7%			
AUE Sao Paulo	DA		51%					45%					
AUE Ribeirao Preto	PA		43%					33%					
AUE Sao Paulo			89%					1%					
AUE Ribeirao Preto	UA		89%					0%					

	Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>migh</b> resolution
<b>esa</b>	Issue	Date	Page	and cover
	2.rev.1	01/02/2023	57	cci

### 3.3.5 Amazon 1995

Following existing land cover maps are used for inter-comparison of historical products for 1995:

- MapBiomas 1995
- GSW seasonality 1995
- GSW v1 2 1995

#### 3.3.5.1 Overall benchmark accuracy

There is only 1 existing multiple-class land cover map – MapBiomas – for year 1995 with which historical product for Amazon region was compared. Table 39 is showing the consistency between historical map in Amazon and the existing land cover map.

Table 39. Overall benchmark accuracy	for whole Amazon in 19	995
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Existing dataset	OA <sub>b</sub>
MapBiomas	56%

Amazon results of OA<sub>b</sub> will be shown in form of maps for OA<sub>b</sub>. OA<sub>b</sub> with respect to MapBiomas is shown in Figure 23. The MapBiomas dataset does not completely cover zoom area in Amazon.



Figure 23. OA<sub>b</sub> for each tile of 1995 historical map in Amazon based on MapBiomas

Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>migh</b> resolution
Issue	Date	Page	and cover
2.rev.1	01/02/2023	58	CCI

## 3.3.5.2 Per class benchmark accuracy

Table 40.	UA <sub>b</sub> and	PA <sub>b</sub> for	whole	1995	Amazon
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Dataset	ndex	Bareland	Built-up	Cropland	Forest	Grassland	Shrubland	Water	Water permanent	Water seasonal	Wetland Herbaceous	Wetland Shrubby
MapBiomas		39%	70%	39%	91%	58%	7%	63%			52%	0%
GSW seasonality	PA								67%	3%		
GSW v1 2									74%	3%		
MapBiomas		1%	21%	35%	65%	75%	24%	52%			17%	0%
GSW seasonality	UA								45%	4%		
GSW v1 2									42%	10%		

## 3.3.6 Amazon 1990

Following existing land cover maps are used for inter-comparison of historical products for 1990:

- MapBiomas 1990
- GHS BU LDS 1990
- GSW seasonality 1990
- GSW v1 2 1990
- AUE 1988 (Sao Paolo), 1990 (Ribeirao Preto)

### 3.3.6.1 Overall benchmark accuracy

There is only 1 existing multiple-class land cover map – MapBiomas – for year 1990 with which historical product for Amazon region was compared. Table 41 is showing the consistency between historical map in Amazon and the existing land cover map.

#### Table 41. Overall benchmark accuracy for whole Amazon in 1990

Existing dataset	OA <sub>b</sub>
MapBiomas	56%

Amazon results of OA<sub>b</sub> will be shown in form of maps for OA<sub>b</sub>. OA<sub>b</sub> with respect to MapBiomas is shown in Figure 24. The MapBiomas dataset does not completely cover zoom area in Amazon.

	Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>Figh</b> resolution
<b>esa</b>	Issue	Date	Page	and cover
	2.rev.1	01/02/2023	59	CCI



Figure 24. OA<sub>b</sub> for each tile of 1990 historical map in Amazon based on MapBiomas

### 3.3.6.2 Per class benchmark accuracy

Table 42.	UA <sub>b</sub> and	PA <sub>b</sub> for	whole	<b>1990</b>	Amazon
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Dataset	Index	Bareland	Built-up	Cropland	Forest	Grassland	Shrubland	Water	Water permanent	Water seasonal	Wetland Herbaceous	Wetland Shrubby
MapBiomas		31%	68%	39%	87%	66%	3%	57%			45%	0%
GHS BU LDS			67%					66%				
GSW v1 2	PA								63%	14%		
GSW seasonality									60%	16%		
MapBiomas		1%	12%	32%	72%	66%	25%	49%			16%	0%
GHS BU LDS			7%					33%				
GSW v1 2	UA								66%	12%		
GSW seasonality									70%	5%		
AUE Sao Paulo			54%					57%				
AUE Ribeirao Preto	PA		57%					0%				
AUE Sao Paulo			84%					8%				
AUE Ribeirao Preto	UA		95%					0%				

Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>migh</b> resolution
Issue	Date	Page	and cover
2.rev.1	01/02/2023	60	CCI

## 3.3.7 Siberia 2015

Following existing land cover maps are used for inter-comparison of historical products for 2015:

- FROM GLC 2015
- GHS BU LDS 2014
- GSW seasonality 2015
- GSW v1 2 2015
- FNF 2015
- WSF 2015

### 3.3.7.1 Overall benchmark accuracy

There is single existing multiple-class land cover maps for year 2015 - FROM-GLC - with which historical product for Siberia region was compared. Table 43 is showing the consistency between historical map in Siberia and each of the existing land cover maps.

Table 43. Ov	verall benchmark	accuracy for	whole Siberia	in	2015
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Existing dataset	OA <sub>b</sub>	
FROM-GLC	53%	

Siberia results of  $OA_b$  will be shown in form of maps for  $OA_b$  with existing land cover available in the region.  $OA_b$  with respect to FROM-GLC is shown in Figure 25.



Figure 25. OA<sub>b</sub> for each tile of 2015 historical map in Siberia based on FROM GLC

	Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>migh</b> resolution
<b>esa</b>	Issue	Date	Page	and cover
	2.rev.1	01/02/2023	61	

# 3.3.7.2 Per class benchmark accuracy

### Table 44. UA<sub>b</sub> and PA<sub>b</sub> for whole 2015 Siberia

Dataset	Index	Bareland	Built-up	Cropland	Forest	Grassland	lce and snow	Shrubland	Tundra	Water	Water permanent	Water seasonal	Wetland
FROM GLC		25%	82%	0%	75%	16%	0%	11%	2%	97%			55%
GHS BU LDS			81%							99%			
WSF			79%										
FNF	PA				78%					91%			
GSW													
seasonality											81%	36%	
GSW v1 2											84%	37%	
FROM GLC		2%	2%	0%	75%	28%	0%	1%	44%	83%			0%
GHS BU LDS			6%							77%			
WSF			9%										
FNF	UA				56%					75%			
GSW													
seasonality											96%	15%	
GSW v1 2											53%	17%	

	Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>Figh</b> resolution
<b>esa</b>	Issue	Date	Page	and cover
	2.rev.1	01/02/2023	62	cci

### 3.3.8 Siberia 2010

Following existing land cover maps are used for inter-comparison of historical products for 2010:

- FROM GLC 2010
- GL30 2010
- GUF 2011
- GSW seasonality 2010
- GSW v1 2 2010
- FNF 2010

#### 3.3.8.1 Overall benchmark accuracy

There are 2 existing multiple-class land cover maps for year 2010 with which historical product for Siberia region was compared: FROM-GLC and GL30. Table 45 is showing the consistency between historical map in Siberia and each of the existing land cover maps.

Table 45. Overall benchm	ark accuracy f	for whole Siberia	in 2010
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Existing dataset	OA <sub>b</sub>
FROM-GLC	53%
GL30	53%

Siberia results of OA<sub>b</sub> will be shown in form of maps for OA<sub>b</sub> with each of the two existing land cover available in the region. OA<sub>b</sub> with respect to FROM-GLC is shown in Figure 26, and with respect to GL30 Figure 27.



Figure 26. OA<sub>b</sub> for each tile of 2010 historical map in Siberia based on FROM GLC

esa	Ref	CCI_HRLC_Ph	<b>Figh</b> resolution	
	Issue	Date	Page	and cover
	2.rev.1	01/02/2023	63	



Figure 27.  $OA_{b}\xspace$  for each tile of 2010 historical map in Siberia based on GL30

	Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>migh</b> resolution
<b>esa</b>	Issue	Date	Page	and cover
	2.rev.1	01/02/2023	64	cci

# 3.3.8.2 Per class benchmark accuracy

## Table 46. UA<sub>b</sub> and PA<sub>b</sub> for whole 2010 Siberia

Dataset	Index	Bareland	Built-up	Cropland	Forest	Grassland	lce and snow	Shrubland	Water	Water permanent	Water seasonal	Wetland
FROM GLC		15%	16%	0%	73%	31%	0%	32%	86%			44%
GL30		82%	51%	0%	77%	13%		0%	89%			21%
GUF 2011			82%									
FNF	PA				87%				87%			
GSW												
seasonality										86%	32%	
GSW v1 2										86%	29%	
FROM GLC		21%	17%	0%	65%	82%	0%	3%	79%			1%
GL30		0%	31%	0%	72%	8%		0%	77%			66%
GUF 2011			10%									
FNF	UA				53%				81%			
GSW												
seasonality										95%	11%	
GSW v1 2										51%	8%	

Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>Figh</b> resolution
Issue	Date	Page	and cover
2.rev.1	01/02/2023	65	CCI

### 3.3.9 Siberia 2005

Following existing land cover maps are used for inter-comparison of historical products for 2005:

- FNF 2007
- GSW seasonality 2005
- GSW v1 2 2005

#### 3.3.9.1 Overall benchmark accuracy

For year 2005 other multiple-class land cover do not exist, therefore OA<sub>b</sub> cannot be reported.

## 3.3.9.2 Per class benchmark accuracy

Dataset	xəpul	Forest	Water	Water permanent	Water seasonal
FNF		86%	88%		
GSW seasonality	PA			89%	32%
GSW v1 2				88%	31%
FNF		55%	77%		
GSW seasonality	UA			92%	13%
GSW v1 2				52%	10%

#### Table 47. UA<sub>b</sub> and PA<sub>b</sub> for whole 2005 Siberia

#### 3.3.10 Siberia 2000

Following existing land cover maps are used for inter-comparison of historical products for 2000:

- GL30 2000
- GHS BU LDS 2000
- TreeCover 2000
- GSW seasonality 2000
- GSW v1 2 2000

#### 3.3.10.1 Overall benchmark accuracy

There is single existing multiple-class land cover maps for year 2000 – GL30 - with which historical product for Siberia region was compared. Table 48 is showing the consistency between historical map in Siberia and each of the existing land cover maps.

Table 48. Overall benchmark accuracy for whole Siberia in 2000

Existing dataset	OA <sub>b</sub>
GL30	50%

Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>migh</b> resolution
Issue	Date	Page	and cover
2.rev.1	01/02/2023	66	CCI

Siberia results of  $OA_b$  will be shown in form of maps for  $OA_b$  with existing land cover available in the region.  $OA_b$  with respect to GL30 is shown in Figure 2.



Figure 28.  $OA_{b}\xspace$  for each tile of 2000 historical map in Siberia based on GL30

esa	Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>migh</b> resolution
<b>esa</b>	Issue	Date	Page	and cover
	2.rev.1	01/02/2023	67	CCI

# 3.3.10.2 Per class benchmark accuracy

## Table 49. UA<sub>b</sub> and PA<sub>b</sub> for whole 2000 Siberia

Dataset	Index	Bareland	Built-up	Cropland	Forest	Grassland	Shrubland	Water	Water permanent	Water seasonal	Wetland
GL30		84%	54%	0%	68%	20%	6%	94%			21%
GHS			83%					99%			
TreeCover	PΔ				83%						
GSW seasonality									88%	46%	
GSW v1 2									86%	39%	
GL30		0%	20%	0%	71%	7%	0%	63%			55%
GHS			3%					76%			
TreeCover	114				68%						
GSW seasonality	UA								96%	15%	
GSW v1 2									52%	13%	

Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>Figh</b> resolution
Issue	Date	Page	and cover
2.rev.1	01/02/2023	68	

### 3.3.11 Siberia 1995

Following existing land cover maps are used for inter-comparison of historical products for 1995:

- GSW seasonality 1994
- GSW v1 2 1994

### 3.3.11.1 Overall benchmark accuracy

For year 1995 other multiple-class land cover do not exist, therefore OA<sub>b</sub> cannot be reported.

### 3.3.11.2 Per class benchmark accuracy

Table 50. UA<sub>b</sub> and PA<sub>b</sub> for whole 1995 Siberia

Dataset	Index	Water permanent	Water seasonal
GSW seasonality	D۸	84%	36%
GSW v1 2	FA	84%	36%
GSW seasonality		95%	16%
GSW v1 2	UA	51%	14%

### 3.3.12 Siberia 1990

Following existing land cover maps are used for inter-comparison of historical products for 1990:

- GHS BU LDS 1990
- GSW seasonality 1990
- GSW v1 2 1990

#### 3.3.12.1 Overall benchmark accuracy

For year 1990 other multiple-class land cover do not exist, therefore OA<sub>b</sub> cannot be reported.

#### 3.3.12.2 Per class benchmark accuracy

#### Table 51. UA<sub>b</sub> and PA<sub>b</sub> for whole 1990 Siberia

Dataset	ndex	Built-up	Water	Water permanent	Water seasonal
GHS		86%	97%		
GSW seasonality	PA			85%	35%
GSW v1 2				84%	33%
GHS		2%	77%		
GSW seasonality	UA			95%	18%
GSW v1 2				53%	15%

### 3.3.13 Africa 2015

Following existing land cover maps are used for inter-comparison of historical products for 2015:

	Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>migh</b> resolution
<b>esa</b>	Issue	Date	Page	and cover
	2.rev.1	01/02/2023	69	CCI

- FROM GLC 2015
- WSF 2015
- GSW v1 2 2015
- GSW seasonality 2015
- GHS 2014
- FNF 2015

### 3.3.13.1 Overall benchmark accuracy

There is single existing multiple-class land cover maps for year 2015 - FROM-GLC - with which historical product for Africa region was compared. Table 52 is showing the consistency between historical map in Africa and the existing land cover map.

Table 52. Overall benchmark accuracy for whole Africa in 2015

Existing dataset	OAb
FROM_GLC	46%

Africa results of  $OA_b$  will be shown in form of maps for  $OA_b$  with existing land cover available in the region.  $OA_b$  with respect to FROM-GLC is shown in Figure 29.

95%	99%	100%	100%	99%	) 100	94% %	72%	75%	42%	45%	42%	54%	57%	42%	84%	96%	97%	98%	5 902	, Das%
8296	99%	99%	70%	48%	85%	<sup>6</sup> 84%	46%	27%	11%	35%	43%	43%	<sup>6</sup> 42%	32%	39%	76%	97%	99%	) <b>85</b> %	25.8
96%	93%	73%	22%	47%	839	<sup>6</sup> 51%	34%	22%	1493	32%	27%	36%	<sup>6</sup> 50%	32%	29%	50%	55%	93%	962	<sup>9</sup> 37%
88%	22%	75%	61%	50%	44%	893	147%	11936	21%	37%	37%	289	<sup>6</sup> 26%	17%	31%	43%	34%	35%	65%	<sup>6</sup> 56%
48%	5%	55%	69%	48%	469	<sup>6</sup> 56%	39%	27%	37%	38%	26%	34%	<sup>6</sup> 51%	25%	26%	36%	23%	15%	339	<sup>6</sup> 94%
55%	57%	55%	61%	59%	59%	6 72%	63%	56%	49%	40%	32%	36%	41%	25%	16%	41%	41%	30%	409	6 9396
58%	53%	63%	45%	52%	59%	<sup>6</sup> 62%	49%	29%	28%	26%	36%	349	<sup>6</sup> 45%	35%	26%	57%	50%	46%	519	<sup>6</sup> 69%
62%	56%	41%	30%	26%	30%	<sup>6</sup> 51%	27%	21%	39%	43%	41%	389	<sup>6</sup> 40%	41%	37%	61%	49%	46%	449	<sup>6</sup> 47%
34%	41%	65%	24%	14	81693	38%	24%	26%	47%	59%	51	%38%	39%	45%	48%	47%	57%	63	%68%	27%
49%	12%	31%	27%	18	181493	28%	36%	2093	54%	83%	62	%48%	30%	40%	38%	52%	56%	62	%41%	52%
21%	21%	21%	28%	33	%33%	32%	44%	28%	45%	60%	51	%40%	31%	37%	54%	48%	36%	52	%44%	74%
29%	18%	15%	22%	289	%		39%	34%	43%	37%	35	% <sup>35</sup>	Ko	11936	1893	50%	51%	65	%71%	63%
53%	72%	54%	50%	35	%23%	46%	39%	46%	54%	65%	48	% 44%	40%	40%	29%	44%	65%	42	% 32%	60%
49%	66%	73%	66%	399	% 32%	46%	54%	38%	45%	28%	70	% 46%	52%	44%	40%	51%	62%	33	% 38%	40%
0	150	3	00 km	E.					OAb F	ROM	GL	C 201	5 💻 :	20 - 40	1 % <b></b>	60 -	80 %		80 - 10	00 %
10									4	- 20 %	6			40 - 60	70					

Figure 29.  $OA_{\rm b}$  for each tile of 2015 historical map in Africa based on FROM GLC

3	.3	.1	3	.2		Per	' <b>C</b>	lass	benc	hm	larl	k	accura	су
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Table 5	3. UA <sub>b</sub>	and PA <sub>b</sub>	for whole	2015 Africa
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Dataset	Index	Bareland	Built-up	Cropland	Forest	Grassland	Shrubland	Water	Water permanent	Water seasonal	Wetland
FROM GLC		61%	21%	23%	85%	20%	44%	86%			45%
GHS	PA		42%					99%			
WSF			33%								

	Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>migh</b> resolution
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Cesa	2.rev.1	01/02/2023	70	CCI

FNF					46%			78%			
GSW									0.2%	17%	
seasonality									9270	4770	
GSW v1 2									93%	38%	
FROM GLC		52%	2%	37%	25%	21%	62%	94%			5%
GHS			1%					89%			
WSF			2%								
FNF	UA				68%			85%			
GSW									100%	00/	
seasonality									100%	070	
GSW v1 2									61%	12%	

## 3.3.14 Africa 2010

Following existing land cover maps are used for inter-comparison of historical products for 2010:

- FROM GLC 2010
- GL30 2010
- GUF 2011
- GSW v1 2 2010
- GSW seasonality 2010
- FNF 2010

### 3.3.14.1 Overall benchmark accuracy

There are 2 existing multiple-class land cover maps for year 2010 with which historical product for Africa region was compared: FROM-GLC and GL30. Table 54 is showing the consistency between historical map in Africa and each of the existing land cover maps.

#### Table 54. Overall benchmark accuracy for whole Africa in 2010

Existing dataset	OAb
FROM_GLC	53%
GL30	28%

Africa results of  $OA_b$  will be shown in form of maps for  $OA_b$  with each of the two existing land cover available in the region.  $OA_b$  with respect to FROM-GLC is shown in Figure 30, and with respect to GL30 Figure 31.

esa	Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>migh</b> resolution
<b>esa</b>	Issue	Date	Page	and cover
Cesa	2.rev.1	01/02/2023	71	cci

99%	100%	99%	97%	97%	979	<sup>6</sup> 99%	86%	94%	92%	85%	85%	87%	<sup>5</sup> 90%	68%	88%	98%	99%	97%	o 719	6 N4%
98%	98%	96%	97%	96%	989	<sup>6</sup> 95%	65%	55%	78%	76%	59%	62%	<sup>6</sup> 62%	57%	56%	86%	98%	99%	5 92 <u>9</u>	49
96%)	94%	8496	67%	85%	899	<sup>6</sup> 87%	51%	44%	48%	50%	36%	34%	<sup>6</sup> 37%	44%	33%	66%	80%	89%	969	<sup>6</sup> 599
55%	63%	45%	46%	62%	659	<sup>6</sup> 52%	59%	31%	26%	28%	44%	48%	<sup>6</sup> 35%	32%	38%	61%	63%	65%	859	<sup>6</sup> 77%
27%	48%	53%	42%	40%	489	<sup>6</sup> 28%	37%	23%	27%	52%	47%	38%	<sup>6</sup> 30%	1293	31%	61%	61%	49%	669	<sup>8</sup> 999
21%	54%	32%	28%	43%	459	6 27%	38%	40%	37%	37%	42%	349	6 25%	18%	28%	66%	61%	52%	679	6 989
65%	55%	37%	45%	55%	549	<sup>%</sup> 52%	50%	49%	56%	52%	44%	459	<sup>6</sup> 39%	35%	2093	49%	71%	82%	819	<sup>66</sup> 869
76%	73%	45%	53%	35%	39%	<sup>%</sup> 53%	37%	24%	61%	53%	50%	46%	<sup>6</sup> 44%	29%	36%	43%	37%	34%	289	<sup>%</sup> 579
81%	60%	41%	33%	23	%24%	33%	22%	20%	49%	62%	57	%40%	37%	43%	45%	21%	36%	68	%60%	689
72%	53%	27%	45%	33	%32%	20%	1193	16%	53%	91%	67	%37%	23%	41%	27%	27%	43%	41	%41%	459
58%	33%	26%	63%	53'	%51%	20%	1993	117%	33%	51%	40	%29%	21%	22%	52%	30%	49%	53'	%51%	569
61%	1593	33%	52%	47	%		25%	23%	45%	39%	42'	%		35%	22%	35%	33%	34	% 44%	619
58%	62%	60%	83%	68	% 58%	69%	39%	67%	71%	43%	46	%33%	46%	38%	42%	46%	46%	62	%63%	769
46%	67%	87%	68%	909	889%	60%	48%	60%	68%	63%	69	% 40%	42%	41%	61%	57%	35%	48	% 39%	369
)	150	3	00 km	1					OAb F	<b>ROM</b>	-GL( %	2010		20 - 40 40 - 60	%	60 -	80 %		80 - 1	00 %

Figure 30. OA<sub>b</sub> for each tile of 2010 historical map in Africa based on FROM GLC



Figure 31.  $OA_b$  for each tile of 2010 historical map in Africa based on GL30
Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>migh</b> resolution
lssue	Date	Page	and cover
2.rev.1	01/02/2023	72	CCI

# 3.3.14.2 Per class benchmark accuracy

Table 55. UA<sub>b</sub> and PA<sub>b</sub> for whole 2010 Africa

Dataset	Index	Bareland	Built-up	Cropland	Forest	Grassland	Permanent ice and snow	Shrubland	Water	Water permanent	Water seasonal	Wetland
FROM GLC		60%	6%	17%	80%	4%	0%	62%	76%			9%
GL30		92%	13%	15%	78%	2%		56%	89%			19%
GUF			23%									
FNF	PA				57%				94%			
GSW										07%	17%	
seasonality										9770	4770	
GSW v1 2										98%	45%	
FROM GLC		90%	1%	33%	39%	19%	0%	39%	95%			1%
GL30		39%	2%	42%	30%	42%		18%	63%			11%
GUF			2%									
FNF	UA				57%				88%			
GSW										05%	26%	
seasonality										95%	20%	
GSW v1 2										66%	47%	

## 3.3.15 Africa 2005

Following existing land cover maps are used for inter-comparison of historical products for 2005:

- GSW seasonality 2005
- GSW v1 2 2005
- FNF 2007

## 3.3.15.1 Overall benchmark accuracy

For year 2005 other multiple-class land cover do not exist, therefore OA<sub>b</sub> cannot be reported.

### 3.3.15.2 Per class benchmark accuracy

Table 56. UA<sub>b</sub> and PA<sub>b</sub> for whole 2005 Africa

Dataset	Index	Forest	Water	Water permanent	Water seasonal
FNF		43%	75%		
GSW seasonality	PA			92%	51%
GSW v1 2				93%	54%
FNF		58%	84%		
GSW seasonality	UA			96%	8%
GSW v1 2				65%	18%

Cesa	Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>Figh</b> resolution
	lssue	Date	Page	and cover
	2.rev.1	01/02/2023	73	cci

## 3.3.16 Africa 2000

Following existing land cover maps are used for inter-comparison of historical products for 2000:

- GL30 2000
- GSW seasonality 2000
- GSW v1 2 2000
- GHS 2000
- TreeCover 2000

### 3.3.16.1 Overall benchmark accuracy

There is single existing multiple-class land cover maps for year 2000 - GL30 - with which historical product for Africa region was compared. Table 57 is showing the consistency between historical map in Africa and the existing land cover map.

#### Table 57. Overall benchmark accuracy for whole Africa in 2000

Existing dataset	OA <sub>b</sub>
GL30	26%

Africa results of  $OA_b$  will be shown in form of maps for  $OA_b$  with existing land cover available in the region.  $OA_b$  with respect to GL30 is shown in Figure 32.

9%	193	193	6%	5%	9%	25%	24%	47%	35%	38%	6%	) 793	1493	1293	1493	38%	70%	67%	35%	A39
21%	493	5%	6%	1093	15%	38%	30%	28%	45%	17%	14%	10%	978	1233	149%	30%	37%	58%	539	19,
8%	6%	993	8%	10%	13%	<sup>9</sup> 28%	26%	2093	27%	26%	49%	37%	23%	17%	13%	29%	45%	38%	65%	<sup>9</sup> 329
79%	193	025	1%	3926	49%	69%	27%	24%	28%	47%	33%	27%	36%	22%	1393	18%	32%	22%	179	<sup>6</sup> 46
2%	193	293	1098 <sup>8</sup>	24%	21%	<sup>6</sup> 22%	21%	1993	40%	52%	39%	41%	9%	30%	23%	15%	1193	19%	22%	<sup>6</sup> 30
0%	193	5%	1998 3	23%	27%	6 23%	20%	29%	39%	52%	50%	48%	46%	35%	26%	1893	23%	25%	31%	19
15%	893	14933	20938	2093	179	<sup>6</sup> 28%	37%	30%	28%	48%	55%	54%	° 50%	36%	30%	18%	11988	13%	15%	5
25%	25%	31%	31%	27%	29%	<sup>6</sup> 44%	41%	24%	27%	37%	50%	43%	° 47%	49%	36%	1293	1876 <sup>8</sup>	23%	279	<sup>6</sup> 22
42%	25%	22%	20%	119%	11936	37%	34%	18%	36%	45%	59	%43%	42%	37%	38%	20%	18%	349	%42%	12
59%	34%	21%	20%	18%	1793	35%	22%	29%	38%	77%	584	%49%	36%	46%	51%	28%	147%	239	626%	20
56%	59%	48%	31%	18%	17%	23%	1293	35%	45%	52%	31	%38%	29%	31%	52%	26%	20%	269	628%	24
38%	33%	45%	36%	18%		23%	30%	43%	40%	36%	19	26		40%	38%	1973	31%	319	633%	21
42%	46%	45%	45%	30%	15%	25%	26%	23%	119%	793	10	81978	1193	26%	21%	22%	14926	189	626%	11
34%	44%	49%	39%	32%	25%	23%	23%	29%	15%	5%	35	78 <sup>593</sup>	1693	18%	35%	48%	23%	169	61493	3
0 150 300 km OAb GL30 2000 20 - 40 % 40 - 60 % 60 - 77 %																				

Figure 32.  $OA_b$  for each tile of 2000 historical map in Africa based on GL30

3.3.16.2 Per class benchmark accuracy

Table 58. UA $_{b}$  and PA $_{b}$  for whole 2000 Africa



Cesa	Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>migh</b> resolution
	Issue	Date	Page	and cover
	2.rev.1	01/02/2023	74	cci

GL30		28%	31%	26%	39%	19%	22%	78%			39%
GHS			53%					99%			
TreeCover	PA				65%						
GSW seasonality									89%	39%	
GSW v1 2									90%	37%	
GL30		20%	1%	33%	46%	41%	10%	69%			10%
GHS			0%					93%			
TreeCover	UA				21%						
GSW seasonality									100%	7%	
GSW v1 2									68%	11%	

## 3.3.17 Africa 1995

Following existing land cover maps are used for inter-comparison of historical products for 1995:

- GSW seasonality 1995
- GSW v1 2 1995

## 3.3.17.1 Overall benchmark accuracy

For year 1995 other multiple-class land cover do not exist, therefore OAb cannot be reported.

#### 3.3.17.2 Per class benchmark accuracy

Table 59. UA $_{b}$  and PA $_{b}$  for whole 1995 Africa

Dataset	Index	Water permanent	Water seasonal
GSW seasonality	П٨	93%	23%
GSW v1 2	PA	95%	42%
GSW seasonality	110	98%	6%
GSW v1 2	UA	68%	13%

### 3.3.18 Africa 1990

Following existing land cover maps are used for inter-comparison of historical products for 1990:

- GHS 1990
- GSW seasonality 1990 (available only for 27 out of 279 tiles)
- GSW v1 2 1990

#### 3.3.18.1 Overall benchmark accuracy

For year 1990 other multiple-class land cover do not exist, therefore OA<sub>b</sub> cannot be reported.

## 3.3.18.2 Per class benchmark accuracy

Table 60. UA<sub>b</sub> and PA<sub>b</sub> for whole 1990 Africa





	Ref	CCI_HRLC_Ph	<b>mage</b> high resolution	
sa	Issue	Date	Page	and cover
	2.rev.1	01/02/2023	75	CCI

GHS		24%	95%		
GSW seasonality	PA			97%	0%
GSW v1 2				97%	7%
GHS		0%	73%		
GSW seasonality	UA			99%	0%
GSW v1 2				27%	0%

### 3.3.19 Conclusions

From the point of view of benchmark accuracy, for binary maps that are specifically derived for certain class – FNF, GHS BU S1, GHS BU LDS, GSW seasonality, GSW\_v1\_2, Tree Cover, and WSF - OA<sub>b</sub> is very high due to the presence of the class that represent all the other classes but the one of interest for the map. Therefore OA<sub>b</sub> for these maps is not informative, and only PA<sub>b</sub> and UA<sub>b</sub> were taken into consideration for the following conclusions.

Regarding individual accuracy indexes the classification are interpreted as "excellent" if both scores  $PA_b$  and  $UA_b$  are above 90%, "well" if the scores are between 70% and 90% and "relatively good" if the scores are between 50% and 70%. The classes for which individual accuracy indexes are less than 50% for the majority of the compared datasets are not considered in the conclusions.

GSW datasets – seasonality and v1\_2 – are the same datasets with different water permanence threshold. GSW v1 2 is dataset produced by JRC, while GSW seasonality is computed form JRC monthly water dataset to take into account seasonality thresholds as defined by CCI HRLC legend. GSW v1 2 defines Seasonal water as a surface that is underwater for less than 12 months of the year and Permanent water as a surface that is underwater throughout the year. In case of GSW seasonality Seasonal water is defined as a surface that is underwater between 4 and 8 months, and Permanent water as a surface that is underwater for 9 or more months. Both datasets are kept for the inter-comparison in order to see if CCI HRLC products are more similar to GSW seasonality which would confirm that water seasonality is captured well. Since in majority of cases the commission error was reduced for few percent in case of GSW seasonality, for the second production only this version of product is considered in the inter-comparison.

### 3.3.19.1 Amazon

Overall agreement of the historical map with existing land cover maps in Amazon varying from 43% to 75%. The best agreement is with the TerraClass dataset, which shows values definitely higher than other datasets.

The agreement with each dataset was relatively homogeneous for different years. The agreement with MapBiomas – the only map available for all years concerned in the project - was around 54% for all the years. The agreement with TerraClass on average for all the years was around 68%, with FROM-GLC around 52% and for GL30 around 44%.

There is no significant difference between results for GSW v1 2 and GSW seasonality so no particular comments were made regarding that.

## 3.3.19.1.1 Amazon 2015

For year 2015 OA<sub>b</sub> was 57% for FROM-GLC and MapBiomas, and 63% for TerraClass (Table 31). The per tile OA<sub>b</sub> for FROM-GLC and MapBiomas are relatively homogeneous too (Figure 12 and Figure 13)

Regarding the class accuracy (Table 32) Forest and Water are considered as relatively good classified, while Permanent water is classified well. From class accuracy it is evident that TerraClass has slightly better records for Forest than the other two datasets and this is probably the reason why OA<sub>b</sub> is higher for this map.

According to the AUE dataset Built-up class is relatively well classified, which is not evident from other datasets. Given that AUE dataset is focused on big cities (Ribeirao Preto and Sao Paolo), it may indicate that classification of built-up class is more successful in cities with respect to built-up elsewhere. It might be due to homogeneity of built-up class in cities.

Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>Figh</b> resolution
Issue	Date	Page	and cover
2.rev.1	01/02/2023	76	CCI

## 3.3.19.1.2 Amazon 2010

For year 2010 OA<sub>b</sub> was 46% for FROM-GLC, 44% for GL30, 51% for MapBiomas, and 67% for TerraClass (Table 33). The per tile OA<sub>b</sub> for FROM-GLC and MapBiomas are relatively homogeneous (Figure 15 and Figure 17), while per tile OA<sub>b</sub> of GL30 shows lower agreement in the central part of the region (Figure 16).

Regarding the class accuracy (Table 34), Forest is the only class considered as relatively good classified. It is surprising that  $UA_b$  is lower than 50% for classes Water and Permanent water since this class is relatively easy to classify due to specific spectral signature. Given that the  $PA_b$  is larger than 70%, it might indicate that water is overestimated. From class accuracy it is evident that TerraClass has slightly better records for Forest than the other two datasets, therefore this is probably the reason why  $OA_b$  is higher for this map.

## 3.3.19.1.3 Amazon 2005

For year 2005 OA<sub>b</sub> OA<sub>b</sub> was 55% for MapBiomas, and 75% for TerraClass (Table 35). The per tile OA<sub>b</sub> for these two maps are not homogeneous (Figure 19 and Figure 20)

Regarding the class accuracy (Table 36) Forest is considered as well classified, while Grassland and Permanent water are considered as relatively good. From class accuracy it is evident that TerraClass has slightly better records for Forest than the other two datasets, therefore this is probably the reason why OA<sub>b</sub> is higher for this map.

## 3.3.19.1.4 Amazon 2000

For year 2000  $OA_b$  was 50% for MapBiomas, and 43% for GL30 (Table 37). The per tile  $OA_b$  for these two maps are not homogeneous (Figure 21 and Figure 22).

Regarding the class accuracy (Table 38), Forest is the only class considered as relatively good classified. As for the year  $2010 \text{ UA}_b$  is lower than 50% for classes Water and Permanent water, but PA<sub>b</sub> is larger than 70%. It might indicate that water is overestimated.

According to the AUE dataset in Sao Paulo and Ribeirao Preto Built-up class might be underestimated as  $PA_b$  is below 50% and much lower than  $UA_b$ .

### 3.3.19.1.5 Amazon 1995

The only existing multiple-class land cover map for 1995 is MapBiomas (Table 39). It is showing 56% of consistency with historical map for 1995 in Amazon. It shows relatively good agreement for Forest, Grassland and Water classes. Second existing land cover map is GSW. It is specialized for water and it is indicating overestimation of Permanent water class given that UA<sub>b</sub> is below 50% and smaller than PA<sub>b</sub> (Table 40).

### 3.3.19.1.6 Amazon 1990

The only existing multiple-class land cover map for 1990 is MapBiomas (Table 41). It is showing 56% of consistency with historical map for 1990 in Amazon. It shows relatively good agreement for Forest and Grassland classes. Other available existing land cover maps are GSW and GHS BU LDS. The former one is specialized for water and it is indicating relatively good classification of Permanent water class. Later one is specialized for built-up areas and in combination with MapBiomas it is showing overestimation of Built-up class. Regarding Built-up class AUE dataset is suggesting relatively good agreement in the big cities (Table 42).

### 3.3.19.2 Siberia

In Siberia there are only two existing land cover maps with multiple-classes available for 3 year 2015, 2010, 2000. This means that  $OA_b$  was estimated only in this years.  $OA_b$  was around 52 % according to the GL30 dataset and around 53% according to the FROM-GLC.

### 3.3.19.2.1 Siberia 2015

According to FROM-GLC consistency with historical map for 2015 is 53% (Table 43). Classes Forest, Water and Permanent Water have UA<sub>b</sub> and PA<sub>b</sub> above 70 % thus the classification of these classes is well (Table 44). UA<sub>b</sub> of Permanent water in case of GSW v1 2 is significantly lower than of GSW seasonality. This indicate that seasonality of Permanent water class is captured well. Per tile OA<sub>b</sub> (Figure 22) is showing high values for areas on the north of the Siberia zoom region which coincide with a sea surface. There are also some areas with very low values of OA<sub>b</sub> (below 20%).

Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>Figh</b> resolution
Issue	Date	Page	and cover
2.rev.1	01/02/2023	77	CCI

## 3.3.19.2.2 Siberia 2010

According to FROM-GLC consistency with historical map for 2010 is 53%, and according to GL30 it is 53% (Table 45). Per tile OA<sub>b</sub> (Figure 22) with FROM-GLC is showing high values for areas on the north of the Siberia zoom region which coincide with a sea surface. Per tile OA<sub>b</sub> with GL30 has very high values in the northern half of the zoom area. This is because Tundra class was removed. This class consists of grass, shrub, bareland and wetland in ecosystem of tundra. After Tundra removal there are very few classes left. The remaining classes are Water, Cropland, Forest, Built-up and Permanent ice and snow. Out of these classes Water, is predominant as other classes are rarely found in the tundra ecosystems. Classes Forest, Water and Permanent Water have UA<sub>b</sub> and PA<sub>b</sub> above 70% thus the classification of these classes is well (Table 46). UA<sub>b</sub> of Permanent water in case of GSW v1 2 is significantly lower than of GSW seasonality. This indicate that seasonality of Permanent water class is captured well.

## 3.3.19.2.3 Siberia 2005

There are no multiple class land cover maps for 2005, thus overall agreement can not be reported. On the opposite binary datasets are showing agreement of some classes (Table 47). In particular there is well agreement for class of Water and Permanent water and relatively good for Forest. UA<sub>b</sub> of Permanent water in case of GSW v1 2 is significantly lower than of GSW seasonality. This indicate that seasonality of Permanent water class is captured well.

## 3.3.19.2.4 Siberia 2000

Consistency of GL30 (the only multi-class existing land cover available) with historical map for 2000 is 50% Table 48. Per tile OA<sub>b</sub> with GL30 has very high values in the northern half of the zoom area. This is because Tundra class was removed. This class consists of grass, shrub, bareland and wetland in ecosystem of tundra. After Tundra removal there are very few classes left. The remaining classes are Water, Cropland, Forest, Built-up and Permanent ice and snow. Out of these classes Water, is predominant as other classes are rarely found in the tundra ecosystems. When individual classes are concerned there is relatively good agreement in case of Forest, and well agreement in case of Water and Permanent Water Table 49. UA<sub>b</sub> of Permanent water in case of GSW v1 2 is significantly lower than of GSW seasonality. This indicate that seasonality of Permanent water class is captured well.

### 3.3.19.2.5 Siberia 1995

There are no multiple class land cover maps for 1995, thus overall agreement can not be reported. For the class agreement, GSW seasonality is showing high scores for Water permanent class thus this class can be considered as well classified Table 50. UA<sub>b</sub> of Permanent water in case of GSW v1 2 is significantly lower than of GSW seasonality. This indicate that seasonality of Permanent water class is captured well.

### 3.3.19.2.6 Siberia 1990

There are no multiple class land cover maps for 1990, thus overall agreement can not be reported. For the class agreement, GSW seasonality is showing high scores for Water permanent and GHS BU LDS for Water class thus class thus these classes can be considered as well classified (Table 51). UA<sub>b</sub> of Permanent water in case of GSW v1 2 is significantly lower than of GSW seasonality. This indicate that seasonality of Permanent water class is captured well.

### 3.3.19.3 Africa

### 3.3.19.3.1 Africa 2015

According to FROM-GLC consistency with historical map for 2015 is 46% (Table 52). There is no other non binary existing HRLC in 2015. Per tile  $OA_b$  (Figure 29) with FROM-GLC is showing high values for areas on the north-west corner of the African zoom region which coincide with a desertic/sandy area. Similarly, in the north-east corner of the zoom region there are high-values which are most probably related to the homogeneous water surface of the Red Sea. When individual classes are concerned there is Excellent agreement for Water permanent, and well agreement for Water class (Table 53). Bareland class has relatively good agreement, with respect to FROM-GLC, but in absence of another existing HRLC to confirm it is not possible to have solid conclusion on this matter.

Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>Figh</b> resolution
Issue	Date	Page	and cover
2.rev.1	01/02/2023	78	CCI

## 3.3.19.3.2 Africa 2010

50% of information of historical map for 2010 coincides with the information of FROM GLC for the same year, on the opposite amount of shared information with GL30 is 28% (Table 54). Per tile OA<sub>b</sub> (Figure 30) with FROM-GLC is showing high values in the northern part of the zoom area, which are most probably due to homogeneous landscape in this area where sand is present in the north-west, and water in the north-east. High values of agreement are evident even the case of GL30 in the north-west (Figure 31). From the class agreement (Table 55) it is possible to see that Water and Permanent water are classified well in 2010. Bareland seems to be relatively good classified according to the FROM-GLC, but not according to the GL30, and this is probably the reason why agreement with GL30 is lower than the agreement with FROM-GLC.

## 3.3.19.3.3 Africa 2005

There are no multiple class land cover maps for 2005, thus overall agreement can not be reported. On the opposite binary datasets are showing agreement of some classes (Table 56). In particular there is well agreement for class of Water and Permanent water.

## 3.3.19.3.4 Africa 2000

In 2000 the only multiple class existing HRLC available is GL30. It has 26% of agreement (Table 57) with CCI HRLC products for this year, which is very low. Per tile  $OA_b$  (Figure 32) does not show any meaningful pattern. The classes that can be considered as well classified are Water and Permanent water (Table 58).

## 3.3.19.3.5 Africa 1995

There are no multiple class land cover maps for 1995, thus overall agreement can not be reported. For the class agreement, GSW seasonality is showing high scores for Water permanent class thus this class can be considered as well classified (Table 59). UA<sub>b</sub> of Permanent water in case of GSW v1 2 is significantly lower than of GSW seasonality. This indicate that seasonality of Permanent water class is captured well.

### 3.3.19.3.6 Africa 1990

There are no multiple class land cover maps for 1990, thus overall agreement can not be reported. For the class agreement, GSW seasonality is showing high scores for Water permanent and GHS BU LDS for Water class thus class thus these classes can be considered as well classified (Table 60). UA<sub>b</sub> of Permanent water in case of GSW v1 2 is significantly lower than of GSW seasonality. This indicate that seasonality of Permanent water class is captured well.

# 3.4 Reliability of existing HRLC in RR regions

To understand how reliable the existing CCI HRLCs are in the regions of interest for the CCI HRLC project, we computed the accuracy of the existing datasets in Round Robin tiles. The accuracy was estimated based on validation samples prepared and provided by UCLouvain. The samples were created for validation of Round Robin tiles.

For computing accuracy metrics of the existing HRLC, it was necessary to harmonize classes from the RR validation dataset with the existing HRLC. Moreover, the CCI HRLC RR tiles legend was adjusted to the legends of different existing HRLCs, and the accuracy of adjusted versions of CCI HRLC RR tiles was estimated so that it is directly comparable with the accuracy of existing HRLC. OA was computed for RR tiles in each region individually, as well as for all tiles at once. The result of OA for existing HRLC compared with results of OA of CCI HRLC when its legend is adjusted to existing HRLC is displayed in Figure 33. The accuracy of GL30 is significantly lower than the accuracy of CCI HRLC products, but regional maps MapBiomas and ESA DUE Permafrost are more accurate than CCI HRLC products.

Cesa	Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>mage</b> high resolution
	Issue	Date	Page	and cover
	2.rev.1	01/02/2023	79	CCI



### Figure 33. Comparison of OA of existing data and CCI HRLC for all RR tiles

Figure 34 shows the result for RR tiles in Siberia. CCI HRLC is more accurate than GL30 and FROM-GLC, but less accurate than the regional map - ESA DUE Permafrost. Other existing HRLCs have OA comparable to the OA of CCI HRLC.



#### Figure 34. Comparison of OA of existing data and CCI HRLC for Siberia (42WXS)

Figure 35 shows that most of the existing HRLCs have comparable accuracy to the accuracy of CCI HRLC RR in Africa. However, there is an exception in the case of GL30 that has an accuracy lower than the one of CCI HRLC RR.





#### Figure 35. Comparison of OA of existing data and CCI HRLC for Africa (37PCP)

Figure 36 shows the result of OA for existing datasets and CCI HRLC in the RR regions in Amazon. It is evident that CCI HRLC is more accurate than GL30 but less accurate than MapBiomas.



### Figure 36. Comparison of OA of existing data and CCI HRLC for Amazon (21KXT and 21KUQ)

Starting from validation data we also analyzed class accuracy and focused on User's accuracy (UA), especially because that is of interest to us in the existing datasets (Table 61).

Each odd row of Table 61 shows the UA of CCI HRLC products, and each even row is showing the difference in UA with respect to an existing dataset.

It is evident that the accuracy of Bareland and Built-up is higher in the existing datasets, and it is relatively low in CCI HRLC products. It is an indicator that these are the most critical classes that could be improved given that they were more successfully classified in the existing datasets.

From this table, it is also evident why the agreement with GL30 is very low.

Ref	Ref CCI_HRLC_Ph1-D4.1_PVIRa					
Issue	Date	Page	and cover			
2.rev.1	01/02/2023	81	CCI			

Table 61. Comparison of l	JA of existing data and	<b>CCI HRLC for all RR tiles</b>
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	Forest	Water	Bareland	Built-up	Cropland	Grassland	Shrubland	Wetland	Water permanent	Water seasonal	Wetland Herbaceous	Deciduous broadleaf	Evergreen needleleaf	Lichens and mosses
CCI HRLC UA			55%			92%	0%	31%	100%	0%		0%	100%	33%
Difference with ESA DUE			43%			1%	0%	19%	0%	-7%		0%	7%	33%
CCI HRLC UA	76%	73%												
Difference with FNF	3%	11%												
CCI HRLC UA	76%	73%	26%	24%	64%	65%	43%	21%						
Difference with FROM-GLC	-13%	-5%	-43%	-31%	8%	21%	-2%	3%						
CCI HRLC UA				24%										
Difference with GHS BU S1				-43%										
CCI HRLC UA	76%	73%	26%	24%	64%	65%	43%	21%						
Difference with GL30	11%	6%	-56%	-13%	32%	42%	34%	10%						
CCI HRLC UA									94%	0%				
Difference with GSW seasonality									4%	-6%				
CCI HRLC UA	84%	82%	11%	30%	6%	87%	20%				57%			
Difference with MapBiomas	-3%	26%	11%	-16%	6%	13%	-9%				26%			
CCI HRLC UA				24%										
Difference with WSF				-35%										

The accuracy analyses of the existing HRLC showed that in the majority of cases the accuracy of the existing HRLC is comparable to the accuracy of the CCI HRLC products. The only existing HRLC that has lower accuracy than CCI HRLC is GL30, and therefore this dataset is not suitable for inter-comparison and will be excluded from inter-comparison in the second phase of the project. When classes are concerned, the accuracy analyses showed that the accuracy of Bareland and Built-up classes could be improved.

# 3.5 HRLC static maps – the second production

## 3.5.1 Siberia

The static map in Siberia is provided as a set of 392 tiles.

## 3.5.1.1 Inter-comparison with the map of agreement Siberia

Inter-comparison based on the map of agreement and CCI HRLC is presented in Table 62. The map of agreement covers 39% of the Siberian static region. The overall agreement between the two maps is 93%. UA<sub>b</sub> and PA<sub>b</sub> of many classes are very high (more than 80%) including Cropland, Forest, Grassland, and Water. On the opposite, Built-up appears to be overestimated (high PA<sub>b</sub>, but low UA<sub>b</sub>), while the accuracy of Shrubland is low. The accuracy of Wetland is not extremely low, but it is not sufficient either. The accuracy of Bareland is "Relatively good" with a PA<sub>b</sub> of 83% and a UA<sub>b</sub> of 58%. There were no pixels classified as Permanent ice and snow in the CCI HRLC, so the accuracy of this class is 0. Cells highlighted in green show the number of correctly classified pixels according to the map of agreement. Cells highlighted in orange show commission errors larger than a class's agreement. The highest error is in the case of Shrubland. Cells highlighted in red show omission errors larger than a class's agreement. An omission error larger than the agreement is present in the case of the Shrubland class for which pixels were prevalently wrongly classified as Grassland, and somewhat less frequently as Wetland. Even though some classes are affected by the error, OA<sub>b</sub> is still high because the affected classes are smaller than the classes with high accuracy.

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## Table 62. Error matrix of map of agreement and CCI HRLC

	Bareland	Built-up	Cropland	Forest	Grassland	Permanent ice and snow	Shrubland	Water	Wetland	PA <sub>b</sub>	OAb	UA <sub>b</sub>
Bareland	38,229,051	116,720	527,000	2,455,367	11,436,445	166,265	24,705	10,045,394	2,878,512	83%	58%	
Built-up	211,846	4,772,152	4,231,271	3,035,469	4,521,810	16,749	388	543,745	302,232	94%	27%	
Cropland	44,042	111,024	2,254,735,814	19,258,902	253,191,695	1,256	454	277,969	11,311,459	90%	89%	
Forest	77,114	20,621	10,544,805	10,371,033,084	190,862,239	1,397	40,943	23,006,729	40,931,103	98%	98%	
Grassland	3,609,465	55,531	205,728,265	150,380,287	2,726,292,501	36,758	1,064,423	7,418,645	39,809,757	81%	87%	0.20/
Permanent ice and snow	0	0	0	0	0	0	0	0	0	0%	0%	95%
Shrubland	14,305	311	660,845	18,352,834	18,320,267	90	168,608	411,075	5,587,492	11%	0%	
Water	3,718,508	9,669	579,775	9,808,035	8,071,793	134,380	3,711	3,905,829,243	53,008,950	99%	98%	
Wetland	225,633	1,745	19,710,393	60,665,072	164,721,975	317	199,881	14,597,915	194,082,255	56%	43%	

Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>Figh</b> resolution
lssue	Date	Page	and cover
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Besides  $OA_b$  for the whole of Siberia,  $OA_b$  for each tile of CCI HRLC is computed to observe spatial variation (Figure 37). Spatial variation does not appear to be strong. There are only several tiles with an accuracy smaller than 80%

																g	99%	96	<b>%</b>
			_						_					10	0%	9	5%	92	2%
				99	9%					10	00%	10	00%	99	9%	9	7%	9	2%
	_			98	3%	100%	<b>100%</b>	1		10	00%	99	9%	96%	96%	7 98	3%	95%	6 <mark>95%</mark>
		10	00%	94	<b>%</b>	99%	99%	99	%	97%	97%	10	0%	96%	96%	93	%	96%	97%
		9	9%	94	%	g	9% /	95	%	ę	96% /	99	%	g	7% /	97	%	<u>و</u>	93%
		9	98%	969	%	ę	99%	919	% [	1	93%	98	%	g	97%	979	%	8	89%
		100	0%	919	6	99	%	99%	6	97	%	939	%	949	8	929	6	86%	
		85%	6	93%	6	999	6	98%	6	989	26	929	6	819	6	92%	6	85%	
	89	%	93%	95%	6 99	9% 3	100%	93%	8 <del>9</del> 4	4%	91%	849	6 91	<b>%</b>	93%	95%	6	90%	
	919	6	89%	96%	6	98%	91%	92%	6	91%	90%	87%	6	95%	96%	97%	5	92%	
	8	9%	88%	84%	5 6	35%	93%	94%	5 9	93%	90%	92%	8 8	07%	93%	95%	6	93%	
	91	.%	92%	92%	8 8	9%	86%	83%	9 9	3%	90%	93%	5 9	5%	96%	97%	9 9	6%	
	97	%	95%	93%	92	29%	88%	90%	92	2%	86%	93%	96	596	95%	98%	98	3%	
	97	%	97%	88%	9	3%	92%	88%	8	1%	82%	88%	9	4%	97%	98%	9	8%	
	90	5%	95%	94%	9	7%	91%	97%	9	98%	93%	88%	9 9	1%	99%	99%	9	99%	
	9	5%	95%	94%	6	97%	98%	96%		97%	96%	98%	9	98%	98%	99%	98	<b>%</b>	
	94	1%	90%	98%	9	4%	96%	98%	9	98%	94%	96%	9	7%	97%	96%	979	26	
	97	%	96%	99%	9	8%	98%	98%	9	7%	93%	83%	8	9%	86%	91%	95%	6	
91	% (	39%	92%	94%	98	8%	98%	99%		97%	96%	90%	90	9%	95%	98%	99%	6	
92	%	92%	91%	91%	93%	92%	5 97%	96%	86%	88%	96%	94%	93%	95%	96%	98%	99%		
90	%	87%	83%	85%	84%	81%	84%	88%	89%	93%	697%	96%	94%	95%	594%	94%	95%		
849	<i>6</i>	79%	80%	77%7	77%	79%	683%	78% 8	34%	83%	86%	90%	92%	90%	694%	96%	88%		
8	8%	85%	89%	88%	91%	90%	87%	88%	82%	82%	85%	89%	88%	94%	87%	95%			
8	9%	93%	89%	89%	92%	94%	95%	92%	88%	85%	86%	90%	90%	86%	94%	95%	95%	-	
8	7%	90%	91%	91%	94%	97%	96%	93%	88%	93%	89%	92%	92%	89%	91%	96%	95%		
90	0%	84%	88%	85%	91%	98%	97%	95%	89%	89%	90%	91%	91%	85%	92%	93%	90%		
									AO										





To understand better if there is a pattern in disagreement, we analyzed the correlation of  $OA_b$  with landscape indices of diversity and fragmentation. In particular, we analyzed the correlation of the Shannon index, Diversity index, Shape index, and Edge density index.

# 3.5.1.2 Correlation of benchmark accuracy with landscape structure indexes

250

500 km

٥

Benchmark accuracy patterns were analyzed by means of the correlation of OA<sub>b</sub> with landscape structure indices and class proportion of CCI HRLC. The values of each variable were collected for each tile in a region. The correlation of the considered variables for Siberian tiles is displayed in correlation matrices (Figure 38). The figure consists of three subplots, one for overall correlation for all tiles, one for tiles with OA<sub>b</sub> in the range from 0% to 80%, and one for tiles with OA<sub>b</sub> greater than 80%. In general, OA<sub>b</sub> in Siberia is above 77% which is high. There is no strong correlation of OA<sub>b</sub> with landscape structure indices in all tiles concerned, as well as in the case of OA<sub>b</sub> interval 80% - 100%. An increase of correlation is evident in the case of OA<sub>b</sub> interval 0-80%, however, it was based on 6 tiles only, and therefore it is not enough representative.

To support correlation matrix analyses, box plots were created to better describe the distribution of the variables considered for correlation analyses (Figure 39). They were created for the same  $OA_b$  intervals as correlation matrices. For this purpose, the landscape structure indices were normalized so that they can be displayed with other variables that are in the range of 0 - 1. From the boxplot for all tiles, it can be seen that the Forest is the most dominant class in Siberia, which is probably the reason for the overall high  $OA_b$  in Siberia.

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*OA<sub>b</sub>* in interval 80% - 100%, 387 tiles Correlation matrix



Figure 38. Correlation of landscape structure indices with OAb, landscape structure indices, and class proportion.

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	Issue	Date	Page	and cover
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Siberia

OA<sub>b</sub> in interval 0% - 20%, 6 tiles Box plot 1.0 0.8 ¢ 0.6 0.4 Ē 0.2 ¢ ₫ ⊨ 0.0 Parameter Parame 085

Figure 39. Box plot of OA<sub>b</sub>, normalized landscape structure indices, and class proportions

### 3.5.1.3 Overall benchmark accuracy with existing HRLCs

In Siberia, there are 2 existing multiple-class land cover maps with which static product for the Siberia region was compared one by one: ESA DUE GlobPermafrost, and FROM-GLC. Table 63 is showing the consistency between the static map in Siberia and each of the existing land cover maps.

Fable 63. Overall benchmark accuracy for the whole Siberia v
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Existing dataset	OA <sub>b</sub>
FROM-GLC 2017	60%
ESA DUE GlobPermafrost 2016	43%

Given that there are many tiles the results of OA<sub>b</sub> per tile will be displayed in the form of maps of tiles with associated values of OA<sub>b</sub>. There are two OA<sub>b</sub> maps, one for inter-comparison with FROM GLC (Figure 40), and one with ESA DUE GlobPermafrost (Figure 41). Some of the tiles have more than one value displayed. The second

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value is for the tile that is underneath the displayed one. For most of the tiles, the  $OA_b$  values for overlapping tiles are similar.

															31	1%	20%
								_					73	2%	8	26	17%
			8	7%					8	5%	28	3%	1	9%	89	26	9%
			47	7%	80%	80%	7		6	6%	18	926	69	66%	69	8	7%7%
	74%	70%	45	%	52%	50% /	55	%	20%	17%	38	%	5%	5%	7%	6	8% 8%
		36%	37	%	5	i4% /	15	26		13%	30	%	89	ð 8%	9%		8% 8%
ſ		41%	339	% T	4	16%	119	26		10%	14	26		10%	19%	5	15%
	60	%	219	%	529	%	419	6	13	86	7%	5	17	%	15%	3	4%
	16	26	25%	6	499	6	22%	6	25	%	9%	<b>)</b>	16	26	51%	34	1%
2	2%	20%	22%	6 70	%	47%	13%	3 20	0%	19%	30%	52	2%	65%	58%	51	% /
54	%	38%	41%	6 5	50%	33%	25%	5 .	43%	34%	59%		79%	82%	81%	639	X6
	53%	42%	32%	4	1%	59%	51%	. 5	51%	52%	59%	7	8%	70%	81%	70%	6
6	6%	66%	57%	46	5%	41%	41%	4	2%	60%	73%	7	5%	76%	87%	78%	,
7	7%	75%	62%	53	%	51%	50%	49	9%	64%	72%	74	%	78%	89%	90%	
8	4%	75%	49%	55	5%	46%	40%	4	0% /	59%	65%	73	3%	79%	89%	93%	
	77%	72%	60%	5	1%	50%	64%	7	2%	53%	51%	6	0%	90%	93%	97%	5
1	59%	63%	63%	6	8%	74%	68%		51%	62%	76%	7	2%	75%	81%	83%	
1	57%	55%	72%	6	4%	75%	79%	7	5%	56%	68%	6	7%	61%	67%	83%	
6	8%	58%	73%	57	7%	67%	60%	6	5%	65%	62%	58	8%	55%	69%	81%	
3%	60%	68%	70%		59%	67%	71%		78%	78%	74%		71%	82%	88%	97%	
0%	76%	74%	74%	79%	81%	89%	81%	57%	60%	72%	86%	83%	86%	6 <b>89%</b>	95%	96%	
29%	73%	71%	78%	75%	75%	76%	78%	75%	739	68%	73% (	32%	849	684%	85%	86%	
%	71%	73%	71% (	59%	699	6 74%	73% 7	76%	74%	72%	77%7	78%	789	% <mark>83%</mark>	87%	76%	
81%	76%	79%	77%	75%	68%	68%	77%	69%	71%	74%	79%	76%	85%	75%	77%		
80%	81%	78%	80%	82%	81%	76%	67%	70%	73%	78%	80%	77%	72%	79%	80%	84%	
66%	58%	72%	75%	80%	95%	93%	82%	71%	71%	79%	83%	81%	74%	78%	88%	88%	
50%	42%	40%	47%	65%	92%	96%	91%	85%	83%	80%	81%	80%	74%	80%	83%	78%	

Figure 40. OAb for each tile of the static map in Siberia based on FROM GLC

The ESA DUE GlobPermafrost size is smaller than the static area in Siberia therefore the appearance of the map is different from the previous two maps.

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#### Figure 41. OAb for each tile of the static map in Siberia based on ESA DUE GlobPermafrost

The overall agreement of the static map in Siberia is 60% with FROM-GLC and 43% with ESA DUE GlobPermafrost (Table 63). The agreement with FROM-GLC increased by 10% compared to the first production, but the agreement with ESA DUE GlobPermafrost decreased by 3%. In the case of comparison with FROM-GLC, there are very low values in the North-East of the static region (Figure 40). Some error matrices in the region with low OA<sub>b</sub> were verified (44XPF, 45WVV, 44WPE). They are showing that the most important confusion is between Lichens and mosses in FROM-GLC and Grassland in CCI HRLC. Probably this is the reason for having low OA<sub>b</sub> values in the North-West side of the static region.

Comparison of CCI HRLC with ESA DUE GlobPermafrost shows an area in the eastern part with a very low agreement. Analyses of tiles in the critical region (44WMV, 43WFT, and 43WET) show that the greatest discrepancies are related to the confusion of Grassland in CCI HRLC with Shrub cover evergreen and Bareland in ESA DUE GlobPermafrost.

### 3.5.1.4 Per class benchmark accuracy with existing HRLCs

For Siberia according to Table 64 classification of Forest, and Water is "Well", and the classification of Cropland and Forest evergreen needleleaf is "Relatively good". For other classes, no conclusions can be made because computed accuracy indexes are showing very different values for the same class depending on the existing HRLC used for computation. Agreement concerning Cropland and Forest evergreen needleleaf classes notably increased in the second production. A slight increase in agreement for the Forest class is also evident.

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Table 64	UA <sub>b</sub> and	PA <sub>b</sub> for	the	whole	of	Siberia
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Existing LC	Index	Bareland	Built-up	Cropland	Forest	Forest deciduous broadleaf	Forest evergreen needleleaf	Grassland	Lichens and Mosses	Permanent ice and snow	Shrubland	Shrubland evergreen	Water	Wetland
FROM GLC		38%	66%	88%	93%			50%	5%	0%	5%		96%	38%
ESA DUE GlobPermafrost		16%				22%	75%	63%	64%			0%	93%	49%
FNF	DA.				83%								86%	
GSW seasonality	ΓAb												86%	
GHS BU S1			40%											
WSF			66%											
FROM GLC		21%	18%	56%	84%			53%	77%	0%	0%		86%	6%
ESA DUE GlobPermafrost		34%				26%	64%	16%	43%			78%	98%	10%
FNF	114				68%								76%	
GSW seasonality	UAb												88%	
GHS BU S1			38%											
WSF			23%											

### 3.5.2 Amazon

The static map in Amazon was provided as a set of 568 tiles.

### 3.5.2.1 Inter-comparison with the map of agreement Amazon

Inter-comparison based on the map of agreement and CCI HRLC is presented in Table 65. The map of the agreement covers 51% of the Amazon static region. The overall agreement between the two maps is 91%. UA<sub>b</sub> and PA<sub>b</sub> of many classes are very high (more than 80%) including Cropland, Forest, and Water. On the opposite, Bareland, Built-up, and Grassland appear to be overestimated (high PA, but low UA<sub>b</sub>), while Shrubland is underestimated. The accuracy of Wetland is low overall. Cells highlighted in green show the number of pixels that are correctly classified according to the map of agreement. Cells highlighted in orange show commission errors that are larger than the agreement of a class. Many pixels were classified as Bareland even if they are Cropland, Forest, Grassland, Shrubland, and Water. Many pixels were classified as Wetland even if they are Water. Cells highlighted in red show omission errors that are larger than the agreement is present in the case of the Shrubland class for which pixels were wrongly classified as Grassland. Even though some classes are affected by the error, OA<sub>b</sub> is still high because the affected classes are smaller than the classes with high accuracy

Cesa	Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>Figh</b> resolution
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## Table 65. Error matrix of map of agreement and CCI HRLC

	Bareland	Built-up	Cropland	Forest	Grassland	Shrubland	Water	Wetland	ΡΑ	UA	OA
Bareland	1,670,300	655,006	7,439,805	5,784,313	30,286,067	9,239,906	3,603,364	87,103	74%	3%	
Built-up	38,269	47,836,157	6,533,948	2,369,430	13,244,959	3,204,729	408,407	8,192	95%	65%	
Cropland	2,908	70,988	3,915,693,850	61,061,557	174,372,847	48,351,865	323,559	183,765	93%	93%	
Forest	84,815	101,248	18,432,202	21,766,498,693	122,436,396	492,175,616	1,399,969	12,063,027	99%	97%	01%
Grassland	29,935	1,488,477	282,375,675	156,676,397	4,237,088,072	1,502,379,678	3,933,475	20,067,813	92%	68%	91%
Shrubland	30	10,977	1,409,067	76,731,072	23,351,676	1,238,674,304	16,323	139,965	38%	92%	
Water	433,760	29,742	77,850	1,613,290	1,581,432	336,533	1,307,331,621	1,074,713	96%	100%	
Wetland	3,152	18,067	422,643	4,915,821	3,251,670	1,657,966	44,332,724	22,589,036	40%	29%	

Cesa	Ref	Ref CCI_HRLC_Ph1-D4.1_PVIRa					
	Issue	Date	Page	and cover			
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Besides  $OA_b$  for the whole of Amazon,  $OA_b$  for each tile of CCI HRLC is computed to observe spatial variation (Figure 42). Spatial variation does not appear to be strong. There are only several tiles with an accuracy smaller than 80%



Figure 42. OA<sub>b</sub> of each tile in Amazon based on the map of agreement

## 3.5.2.2 Correlation of benchmark accuracy with landscape structure indexes

Benchmark accuracy patterns were analyzed by means of the correlation of OAb with landscape structure indices and class proportion of CCI HRLC. The values of each variable were collected for each tile in a region. The correlation of the considered variables for Amazonian tiles is displayed in correlation matrices (Figure 43). The figure consists of three subplots, one for overall correlation for all tiles, one for 0 - 80% interval of OA<sub>b</sub>, and one for OA<sub>b</sub> values above 80%. The overall correlation matrix shows a moderate positive correlation of OA<sub>b</sub> with the Dominance index and a moderate negative correlation with the Shannon index. This indicates that the landscape tends to be dominated by a class. From the correlation of these two indices with pixel counts of each class, it is evident that the Dominance is strongly positively correlated with the Forest class, and moderately negatively correlated with Grasslands, Croplands, and Shrubland classes. In other words, the dominance of the Forest class leads to higher OA<sub>b</sub>, while lower OA<sub>b</sub> is associated with a higher number of Grassland, Cropland, and Shrubland classes. Fragmentation indices, Shape, and Patch density are strongly negatively correlated with OAb. The indices are moderately positively correlated with the number of pixels in the Grassland, and Shrubland classes, and negatively moderately correlated with the Forest class. This indicates that fragmentation of landscape (more patches or longer borders among different classes) is more intense in the case of the Grassland, and Shrubland classes, and that higher fragmentation leads to lower  $OA_b$ . The results in the  $OA_b$  80% - 100% interval are consistent with the overall correlation matrix, except for the correlation of Shrubland with landscape structure

esa	Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>Figh</b> resolution
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indexes which is lower for this interval. The correlation matrix for the 0% - 80% interval does not show an important correlation OA<sub>b</sub> with landscape indices. A more detailed analysis of the correlation can be done by splitting further 0% - 80% interval into 4 intervals with a 20% step (Figure 44), however due to the high variation of the number of tiles per interval and the very low number of tiles in an interval the results should be interpreted prudently. For example, we can see that in the  $OA_b 0\%$  - 20% the correlation is computed based on the variables for 4 tiles only, thus even if there is a strong correlation, the number of tiles is rather small to make relevant conclusions. In other intervals, the correlation does not appear to be strong.



Amazon



Figure 43. Correlation of landscape structure indices with OA<sub>b</sub>, landscape structure indices, and class proportion for different OA<sub>b</sub> intervals. The subplot in the upper left corner refers to all OA<sub>b</sub> values, the one in the upper right corner refers to the subset of OA<sub>b</sub> values in the 0% - 80% interval, and the one in the lower left corner refers to OA<sub>b</sub> subset with values above 80%

-0.75

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#### Amazon

Figure 44. Correlation of landscape structure indices with OA<sub>b</sub>, landscape structure indices, and class proportion for different OA<sub>b</sub> intervals. The subplot in the upper left corner refers to the subset of OA<sub>b</sub> values in the 0% - 20% interval, the subplot in the upper right corner refers to the subset of OA<sub>b</sub> values in the 20% - 40% interval, Subplot in the upper left corner refers to the subset of OA<sub>b</sub> values in the 40% - 60% interval, Subplot in the upper left corner refers to the subset of OA<sub>b</sub> values in 60% - 80% interval.

To support correlation matrix analyses, box plots were created to better describe the distribution of the variables considered for correlation analyses (Figure 45, Figure 46). They were created for the same  $OA_b$  intervals as correlation matrices. For this purpose, the landscape structure indices were normalized so that they can be displayed with other variables that are in the 0 - 1 range. From the boxplots for all tiles, the Forest is the most dominant class in the Amazon, which is probably the reason for the overall high  $OA_b$  in Amazon. Furthermore, it can be observed that the proportion of the Grassland class is higher than the proportion of the Forest class in the  $OA_b 0\% - 80\%$  interval, and it is the opposite in the 80% - 100%. The proportion of the Shrubland and Cropland classes is lower in the 80% - 100% interval. The dominance index is higher, and Shannon, Shape, and Patch density indices are lower for the 80% - 100% interval than for the 0% - 80% interval.

esa	Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>migh</b> resolution
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Amazon





Figure 45. Box plot of OA, normalized landscape structure indices, and class proportions. The subplot in the upper left corner refers to all OA<sub>b</sub> values, the one in the upper right corner refers to the subset of OA<sub>b</sub> values in the 0% - 80% interval, and the one in the lower left corner refers to OA<sub>b</sub> subset with values above 80%.

esa	Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>mage</b> high resolution
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	2.rev.1	01/02/2023	94	CCI



Figure 46. Box plot of OA<sub>b</sub>, normalized landscape structure indices, and class proportions. The subplot in the upper left corner refers to the subset of OA<sub>b</sub> values in the 0% - 20% interval, the subplot in the upper right corner refers to the subset of OA<sub>b</sub> values in the 20% - 40% interval, Subplot in the upper left corner refers to the subset of OA<sub>b</sub> values in the 40% - 60% interval, Subplot in the upper left corner refers to subset of OA<sub>b</sub> values in 60% - 80% interval.

### 3.5.2.3 Overall benchmark accuracy with existing HRLCs

In Amazon, there are two existing multiple-class land cover maps with which static product for the Amazonian region was compared one by one: MapBiomas, and FROM-GLC. Table 66 is showing consistency between the static map in Amazon and each of the existing land cover maps.

Existing dataset	OAb
FROM-GLC 2017	76%
MapBiomas 2019	75%

Table 66. Overall benchmark accuracy for the whole Amazon v2

Given that there are many tiles the results of OA<sub>b</sub> per tile will be displayed in the form of maps of tiles with associated values of OA<sub>b</sub>. There are 3 OA<sub>b</sub> maps, one for inter-comparison with FROM GLC (Figure 47), and one for CCI Prototype (Figure 48). Some of the tiles have more than one value displayed. The second value is for the tile that is underneath the displayed one. For most of the tiles, the OA<sub>b</sub> values for overlapping tiles are similar.

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g	97%	98%	99%	89%		889	6	96%		94%		74%		74%	5	93	%	
9	98%	97%	84%	81%	8	4%	93%	6	94%		86%			74%	5 (	86%	84%	
	34%	83%	86%	96%	9	3%	85%	6	89%		86%	72	2%		64%		64%	
	94%	92%	98%	97%	92%	979	2	93%		81%		72%		70%		53%	70%	
	96%	98%	99%	95%	9	9%	98%	6	87%		78%			73%		58%	71%	
	96%	100%	98%	97%	98%	929	76	87%	5	79%	) (	62%		53%		56%	62%	
	97%	95%	96%	90%	Π	949	6	86%	5	80%	) (	49%		50%		62%	61%	
	98%	99%	95%	91%	9	9%	97%	6	80%	,	72%	51	%		57%		53% UAb rar	g
	97%	99%	98%	91%	1	00%	92%	6	76%		67%	44	1%		61%		32% 20	-
	96%	92%	90%	89%		6%	92%	6	80%		64%			38%		55%	32% 40	_
	98%	91%	89%	82%	, 8	9%	82%	6	74%		64%	40	)%		59%		39% 60	_
	95%	94%	88%	85%	, (	3%	84%	6	67%		63%	,		57%	, (	44%	35% 80	_
	90%	78%	92%	90%		93%	90%	6	66%	)	65%	63	3%	) (	61%		48%	
	87%	68%	88%	90%	. 8	34%	79%	6	73%		60%			66%	, ,	49%	48%	
	88%	73%	80%	79%		65%	6	75%		64%		53%		57%		34%	50%	
	86%	73%	78%	69%		719	6	78%		65%	5	58%	,	47%		49%	49%	
	67%	64%	72%	73%		68%	6	70%	5	64%		62%	5	55%		50%	51%	
	84%	71%	58%	70%		58%	66%	5	71%	,	70%	66	%		50%		52%	
	64%	94%	59%	72%		73%	73%	5	80%		70%	b		59%		48%	50%	
	58%	92%	66%	74%	. (	81%	78%		75%	6	67%	69	%		59%		57%	
	49%	80%	68%	76%	5	80%	6	81%		71%	6	77%	6 (	58%		68%	66%	
	22%	45%	75%	84%	5	82%	81%	6	79%		85%	6 74	%	(	69%		67%	
	30%	57%6	9%75%	83%82%	81%	90%	80%	79%	78%	79%	83%	6 75	%(	59%	66%	68%	66%	
	45%	55%7	6%80%	79%79%	81%	81%	86%	82%	76%	77%	78%	6 76	%	56%	70%	77%	71%	
		04 669	73%80	0/220/2	20%	76	0/077	07.97	07.9/	10/2 9	20/		7	-			2 01%	

Figure 47.  $\mathsf{OA}_b$  for each tile of the static map in Amazon based on FROM GLC

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Figure 48. OAb for each tile of the static map in Amazon based on MapBiomas

The overall agreement of the static map with existing land cover maps in Amazon is around 75% (Table 66), which is almost 15% more with respect to the first production. The agreement with FROM-GLC and MapBiomas is similar. The agreement is the highest in the North-West area of the region of interest and the lowest in the east. This pattern seems to follow the homogeneity of the landscape which according to Google Satellite base map is a dense rainforest in the North-West and becomes a mix of classes towards the South-East.

## 3.5.2.4 Per class benchmark accuracy with existing HRLCs

Regarding individual classes in Amazon according to Table 67 classification of Permanent Water is "Excellent", the classification of Forest, and Water is "Well", and the classification of Grassland is "Relatively good". For other classes, no conclusions can be made because computed accuracy indexes are showing very different values for the same class depending on the existing HRLC used for computation.

Existing LC	Index	Bareland	Built-up	Cropland	Forest	Grassland	Shrubland	Water	Water permanent	Water seasonal	Wetland	Wetland Herbaceous	Wetland Shrubby
FROM GLC		71%	49%	77%	92%	80%	21%	93%			38%		
MapBiomas	$PA_b$	25%	67%	21%	95%	84%	27%	80%				3%	31%
GHS BU S1			75%										

Table 67	UA <sub>b</sub> and	PA <sub>b</sub> for	the	whole	Amazon
		- Aprol	CIIC.	whitele	AIIIuzoii

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WSF			83%										
FNF					89%			56%					
GSW									02%	12%			
seasonality									9370	1370			
FROM GLC		3%	50%	65%	89%	64%	68%	95%			22%		
MapBiomas		11%	66%	30%	84%	67%	80%	96%				14%	40%
GHS BU S1			37%										
WSF	$UA_b$		41%										
FNF					79%			81%					
GSW									050/	270/			
seasonality									95%	21%			

# 3.5.3 Africa

The static map for Africa was provided as a set of 768 tiles.

## 3.5.3.1 Inter-comparison with the map of agreement Africa

Inter-comparison based on the map of agreement and CCI HRLC is presented in Table 68. The map of agreement covers 4% of the African static region. The overall agreement between the two maps is 92%. UA<sub>b</sub> and PA<sub>b</sub> of many classes are very high (more than 80%) including Bareland, Cropland, Forest, and Water. On the opposite, Cropland and Grassland appear to be overestimated (high PA<sub>b</sub>, but low UA<sub>b</sub>). Wetland leans towards overestimation, however, PA<sub>b</sub> is below 80% and UA<sub>b</sub> is very low - 12%. Shrubland seems to be underestimated, with UA<sub>b</sub> slightly lower than 80% and PA<sub>b</sub> 26%. Cells highlighted in green show the number of pixels that are correctly classified according to the map of agreement. Cells highlighted in orange show commission errors that are larger than the agreement of a class. Many pixels were classified as Wetland even if they are Grassland. Cells highlighted in red show omission errors that are larger than the agreement is present in the case of the Shrubland class for which pixels were wrongly classified as Grassland. Even though some classes are affected by the error, OA<sub>b</sub> is still high because the affected classes are smaller than the classes with high accuracy.

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# Table 68. Error matrix of map of agreement and CCI HRLC

	Bareland	Built-up	Cropland	Forest	Grassland	Shrubland	Water	Wetland	PAb	UA <sub>b</sub>	OA <sub>b</sub>
Bareland	11,971,483,363	144,037	6,736,325	557,390	376,294,279	45,817,379	4,043,103	159,750	98%	97%	
Built-up	1,644,322	6,753,141	3,946,849	1,046,413	2,294,678	462,481	23,639	72	93%	42%	
Cropland	6,083,026	49,125	3,166,384,629	50,019,516	186,148,981	50,598,225	391,316	74,765	85%	92%	
Forest	618,352	3,431	38,353,820	12,023,706,462	12,687,065	2,677,869	442,437	39,596	99%	100%	0.20/
Grassland	271,083,115	235,101	457,060,284	50,813,001	3,516,612,498	944,208,557	705,792	680,945	84%	67%	92%
Shrubland	1,242,318	45,417	34,832,891	20,248,452	81,240,542	371,342,820	20,771	9,370	26%	73%	
Water	572,102	1,908	1,607,841	981,932	1,307,175	64,236	1,901,736,758	442,512	100%	100%	
Wetland	96,828	421	2,067,300	2,481,880	16,882,822	958,259	3,365,187	3,436,121	71%	12%	

	Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>Figh</b> resolution
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Besides  $OA_b$  for the whole of Africa,  $OA_b$  for each tile of CCI HRLC is computed to observe spatial variation (Figure 49). Spatial variation does not appear to be strong. There are only several tiles with an accuracy smaller than 80%

100%1	00% 100%	100%	100%	100%	99%	999	%99%9	9%10	0% 100	<sup>98</sup> 100	%10	00%	100%	100%	99%9	9%99	%98%	698%	98%	8%98	% 100	%100	%	87%
100%	100% 1	00% 1	100%	100%	99% 1	100%	99%9	7%92	% 100	% 100%	<sup>5</sup> 10	0%	100%	3 100%	5 <b>100</b> %	6 999	3 <sup>99%</sup>	99%	95%	395%	96%10	0%		93%
96%9	<b>6% 99%</b>	98% g	98%88%	92% <sup>95</sup>	% <u>{</u>	100%	97%8	1%929	<sup>76</sup> 9	9%99%	99	<b>%10</b> 0	0%	98	% <del>9</del> 9%	95%	6 <b>93</b> %:	79%	86%	688%	84%95	<b>%99</b> %		97%
82%8	2% <b>81</b> %	88% 8	36% <sup>83%</sup>	85%	89%	84%	80%7	9%79	8	5%93%	97	<u>%97</u> 9	<mark>%93</mark> %	92	% <b>97</b> %	92%	3 <sup>78%</sup>	92%	76%	67%	77 <mark>%8</mark> 2	<b>%99%</b>		93%
90%9	4% <u>90</u> %	76% g	93%93%	94%	94%	85%	70%7	9% <sup>789</sup>	6 9	0%77%	74	%68	% <sup>69%</sup>	76	%90%	86%	692%	93%	92%	62%	82%65	% <sup>98%</sup>		99%
04%	970/2	85% e	36%	86%	84%	77%	80%	819	69%	6 80%	94	%	77%	83%	80%	82%	68	36%	80%	69%	75%	94%	<u>ہ</u> د	100%
93%	78%	61%	59%	82%	37%	62%	75%	859	% 85%	6 90% 4 00%	88	%	75%	84%	90%	80%	6 8	35%	68%	95%	78%	53%		96%
73%	0004	84%	/6%	80%		64%	82%	65%	<u>/</u> 5 /0%	57%	51	%	77%	50%	35%	719		52%	0070	95%	85%	6/%	90	2099% 90%
82%	830% 89%	86%	00%	58	% 72%	870	90%	10%	ง กรจะมี	6% 65	06	440	2	0% 57	% 51	%	55%	0	4%) 00%,92%	8 m	3 00%0	0/2	48%	53%
81%	87%93%	96%	93%	5 929	% 49%	33	% %	4%	91%8	3% 53	9%	50	% 8	5%53	% 44	%	64%	9	6% <sup>919</sup>	6 929	6 83	%	58%	21%
73%	96%95%	93%	89%	5 94	% 97%	989	% 1	00%	99%9	4% 37	%	15	% 8	0% 57	% 91	%	87%	9	9%929	6 869	6 50	%	60%	45%
97%	96% 98%	97%	96%	5 <u>95</u>	% <sup>99%</sup>	99	% 9	9%	99%9	<b>17% 9</b> 6	%	75	% 5	7% 38	% 88	3%	93%	9	5%919	6 899	6 87	%	14%	52%
97%	98% 10	0% 9	99%	98%	99%	999	<sup>26</sup> g	8%	99%9	9% 100	%	989	% g	<mark>6%</mark> 31	% 92	8%	93%	8	1% <mark>83</mark> %	8 <b>91</b> 9	<sup>8</sup> 92	%	24%	66%
99%	99% 99%	98%	98%	5 9 <b>5</b> 9	% <mark>97%</mark>	989	<sup>26</sup> 9	8%	99%9	9% 100	% ~	999	% 9	3%86	% 91 %		84%	9	3 <mark>%</mark> 70%	67%	<sup>6</sup> 79	%	26%	58%
99%	98%	99%	99%	5 <u>99</u> 8	% 	989	<sup>26</sup> 9	9%	99%	99	‰ œ	999	<b>%</b> 9	6%	94	820	93%	8	5%	79%	<sup>0</sup> 77	%	37%	50%
100%	99%	100% <u>{</u> %	100%	99%	95 %	070	97%	999	6	100	70	999	<b>%</b> 9	8%	0970	919	68	35%		95%	° 64	.%	75%	51%
100%	99%		100	% <sup>50</sup>		999	~ 9 % 4	8%	99% 100%	100% 99%	10	0%	100%		- 93 - 93	919 3%	8 9	93%		83%	9 6	%	72%	
100%	100	10% 1 % 2	100%	100%	97%	072	~ 1	00%		002	10	0%	100%	94%	/ <u>6</u> 65%		88%	8	2%		46	<i>%</i>	3/%	
	99-%	2	100% 1	00%80	20 95	970	100%	0070	100%9	100	%	100	9707 9	070		95%	97.00	81	% 83%	70%	50%	17%	50%	
0	250	5	00 km					OAb	range															
	250								8.395	3 - 20 0	%	2	20 - 40	)%[	4(	) - 60	%	6	60 - 80	%	80	100	%	



## 3.5.3.2 Correlation of benchmark accuracy with landscape structure indexes

Benchmark accuracy patterns were analyzed by means of the correlation of  $OA_b$  with landscape structure indices and class proportion of CCI HRLC. The values of each variable were collected for each tile in a region. The correlation of the considered variables for African tiles is displayed in correlation matrices (Figure 50). The figure consists of three subplots, one for overall correlation for all tiles, one for 0 - 80% interval of  $OA_b$ , and one for  $OA_b$ values above 80%. Overall correlation matrix does not show a significant correlation of  $OA_b$  with Dominance, Shannon, or Patch density indices, while the correlation with the Shape index is moderate. There is no strong correlation between any of the indices and with classes' pixel counts. This indicates that there is no intense class dominance or landscape fragmentation overall.

The results in the OA<sub>b</sub> 80% - 100% interval show a somewhat higher correlation of different variables than the overall correlation matrix. Landscape indices are more correlated with some classes, however, the correlation is not strong. Week correlation is evident between Shannon, Shape, and Patch density with Croplands, Grassland, and Shrubland in the positive direction, and with Bareland in the negative direction. A more detailed analysis of the correlation can be done by splitting further the 0% - 80% interval of OA<sub>b</sub> into 4 intervals with a 20% step (Figure 51). In the first interval (OA<sub>b</sub> 0% - 20%) the correlation of OA<sub>b</sub> with Patch density is moderate. Patch density and Dominance indices are correlated with Cropland pixel counts. This indicates that the Grassland class is dominant and fragmented in the tiles with low OA<sub>b</sub>. Even though there is a correlation, the number of tiles is rather small concerning the total number of tiles to make relevant conclusions. In other intervals, the correlation does not appear to be strong.

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Africa



Figure 50. Correlation of landscape structure indices with OA<sub>b</sub>, landscape structure indices, and class proportion for different OA<sub>b</sub> intervals. The subplot in the upper left corner refers to all OA<sub>b</sub> values, the one in the upper right corner refers to the subset of OA<sub>b</sub> values in the 0% - 80% interval, and the one in the lower left corner refers to OA<sub>b</sub> subset with values above 80%

Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>Figh</b> resolution
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Figure 51. Correlation of landscape structure indices with OA<sub>b</sub>, landscape structure indices, and class proportion for different OA<sub>b</sub> intervals. The subplot in the upper left corner refers to the subset of OA<sub>b</sub> values in 0% - 20% interval, the subplot in the upper right corner refers to the subset of OA<sub>b</sub> values in the 20% - 40% interval, Subplot in the upper left corner refers to the subset of OA<sub>b</sub> values in the 40% - 60% interval, Subplot in the upper left corner refers to the subset of OA<sub>b</sub> values in the 60% - 80% interval.

To support correlation matrix analyses, box plots were created to better describe the distribution of the variables considered for correlation analyses (Figure 52, Figure 53). They were created for the same  $OA_b$  intervals as correlation matrices. For this purpose, the landscape structure indices were normalized so that they can be displayed with other variables that are in the 0 - 1 range. From the boxplots for all tiles, the Grassland is the most dominant class in Africa, which is probably the reason for the overall high  $OA_b$  in Africa. Furthermore, it can be observed that the proportion of Grassland and Shrubland classes is significantly higher in the  $OA_b 0\% - 80\%$  interval than in the 80% - 100%, while the proportion of the Forest class increased slightly in the second interval. The dominance index is higher, and Shannon, Shape, and Patch density indices are lower for the 80% - 100% interval.

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Figure 52. Box plot of OA<sub>b</sub>, normalized landscape structure indices, and class proportions. The subplot in the upper left corner refers to all OA<sub>b</sub> values, the one in the upper right corner refers to the subset of OA<sub>b</sub> values in the 0% - 80% interval, and the one in the lower left corner refers to OA<sub>b</sub> subset with values above 80%.

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Figure 53. Box plot of OA<sub>b</sub>, normalized landscape structure indices, and class proportions. The subplot in the upper left corner refers to the subset of OA<sub>b</sub> values in the 0% - 20% interval, the subplot in the upper right corner refers to the subset of OA<sub>b</sub> values in the 20% - 40% interval, Subplot in the upper left corner refers to the subset of OA<sub>b</sub> values in the 40% - 60% interval, Subplot in the upper left corner refers to the subset of OA<sub>b</sub> values in the upper left corner refers to the subset of OA<sub>b</sub> values in the 40% - 60% interval, Subplot in the upper left corner refers to the subset of OA<sub>b</sub> values in the 60% - 80% interval.

### 3.5.3.3 Overall benchmark accuracy with existing HRLCs

In Africa, there are two existing multiple-class land cover maps with which static product for the African region was compared one by one: ESA DUE GlobPermafrost, and FROM-GLC. Table 69 is showing the consistency between the static map in Africa and each of the existing land cover maps.

Table 69. Overall benchmark accu	aracy for whole Africa v2
Existing dataset	OA <sub>b</sub>

Existing dataset	OA <sub>b</sub>
FROM GLC 2017	66%
CCI Prototype 2016	57%

Given that there are many tiles the results of OA<sub>b</sub> per tile will be displayed in the form of maps of tiles with associated values of OA<sub>b</sub>. There are 3 OA<sub>b</sub> maps, one for inter-comparison with FROM GLC (Figure 54), and one for CCI Prototype (Figure 55). Some of the tiles have more than one value displayed. The second value is for the tile that is underneath the displayed one. For most of the tiles, the OA<sub>b</sub> values for overlapping tiles are similar.

Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>Figh</b> resolution
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N

10 <mark>0%10</mark>	00%	100%	1009	% <sup>100%</sup>	10	0% 8	99%	99	<b>%98</b> %	%98% <sup>1</sup> (	00%	100	<u>%</u> 1	00%	,100%	1009	899%	99%9	8%9	6%95	%96%	96%	90%8	4%	100%9	98% !	51%
100%	1	100% 1	00%	100%	10	0% 9	9%	100%	989	%94%9 <sup>99</sup>	9%	100%	<b>100</b>	07%	100%	1009	<sub>6</sub> 100%	5 <mark>99</mark> %	98	<b>%91</b> 9	695%	88%	684%	72%	1	00%	70%
86%93	<b>%</b>	98%9	98%	97%8	2%90	86	96%	88%	859	81%89	9%	979	%98	%	95% <sup>99</sup>	<b>%96</b> %	94	<b>%94%</b>	83	%80%	6 <sup>71%</sup>	71%	68%	48%	83%98	37%	81%
81%81	<b>%</b>	74%7	79%	80% <sup>7</sup>	9%80	%	74%	63%	719	678%78	%	71	%74	%	60% <sup>77</sup>	%77%	70	%74%	73	% <sup>60%</sup>	675%	72%	61%	52%	95 <mark>%98</mark>	3%	88%
92%92	%	87%	17%	87%9	0 <mark>%79</mark>	%	89%	685%	759	%79% <sup>68</sup>	% —	60	%70	%	66%70	%77%	63	% <mark>81</mark> %	71	% <sup>83%</sup>	679%	67%	655%	48%	39% <sup>85</sup>	5%	97%
68%	59		52%	51 <mark>%</mark>	83	% 7	1%	78%	739	64	%	63%	77	%	90 <u>%</u>	83%	65%	56%	68	%	73%	57%	37%	40%	65	<b>%</b>	92%
59%	40	59%	57%	55%	53	% 6	8%	62%	65%	6 71	%	76%	72	%	66%	65%	67%	65%	65	%	71%	36%	77%	52%	52	%	82%
49%	40	/035%	200/-	51%	36	% 4	2%	46%	569	% 55	%	49%	52	%	35%	55%	52%	62%	62	%	42%	3/%	64%	51%	53	3% /	5704
51%	66	% v 58%	420	57%	00/	53%	41%	5970	53%	6 33	%	0/ 31	%	220/	66%	0/	43%	% 50	50	%	44%	10( 469	0470	63%	C20/	51%	37%
55%	41	37%	320	% 4	30%	48%	41%	42	%	53%	4/	0% 51	%	51%	45	%	52% 74	% 67	9/0	65%	6 5	10% 549	6 66	9/0 9/6	62%	470/	53%
44%	39	% <sup>18%</sup>	13	20 4	0%	60%	42%	54	%	35%	48	% 43	%	58%	56	%	43% 70	% 80	%	719	6 7	3% 58%	68	%	41%	78%	49%
55%	34	<sub>%</sub> 19%	159	3	0%	34%	26%	6 41	%	34%	52	% 49	%	47%	54	%	42% 59	% 73	%	67%	6 4	7% 389	6 54	%	57%	75%	399
41%	54	<mark>%</mark> 62%	309	% 2	3%	47%	49%	6 31	%	33%	66	% 52	%	53%	51	%	47% 40	% 86	%	83%	6 4	4% 469	6 48	%	49%	86%	53%
74%	74	% <sup>88%</sup>	329	% 2	8%	41%	49%	43 d	%	45%	76	% 67	%	61%	65	%	61% 35	% 68	%	66%	6 6	5% 52%	65	%	78%	79%	43%
92%		94%	849	<sup>26</sup> 7	1%	77%	6	77	%	86%	90	8		58%	56	%	52%	42	%	39%	6 6	5 %	9%	70%	84	%	44%
93%	94	%	100%	<sup>26</sup> 9	9%	99%	6	79	%	95%	97	%		91%	87	% (	54%	19	% ~	29%	6 50	0%	52	%	45%	70%	<b>49</b> %
96%	76	% 99	200	1	00%	96%		89 372	%	90%	91	%		99%	94	% %	97%	14	20	26%	6 4	5%	54	%	37%	74%	D
91%		9970	100; %	9	9%	98%	9	070	969	<b>% 98</b>	%	969	%	39%	98	%	92%	1370	33	%	49%	48%	00	70	39%	39%	5
5170	72	% 55		98% 9	7%	96%	9	9%	100%	699%	99%	8 909	<i>6</i> %	5%	99%	98%	72%	28%	38%	6 55 <sup>9</sup>	64	% 41%	449	6 37%	199	6 32%	3
											OA	h ran	nge														
0		250		500 k	m							10.	.8 -	20	%	20	- 40 %		40 -	- 60 0	%	60 -	80 %		80 -	100 %	6

Figure 54.  $OA_{\text{b}}$  for each tile of the static map in Africa based on FROM GLC

			N
100%100% 100% 100% 100% 100% 100%	884%63%95%100% 100% <sup>100%</sup> 100%	98%98%95%82%85%78% 82%7 98% 80%	8% 78%100%
100% 100% 100% 100% 100% 100% 100% 100%	100%46 <mark>%91</mark> % 100% 100% 100% 100% 1	00% 100% 90%91%89% 75%	91% 73%100%
51%66% 90%97% 85% <sup>74%85%</sup> 93%72%	41% <sup>40%48%</sup> 84% 79% 43%87%84%	50%32% 36%38%48% 33%	20% 31%48%90%
40%52% 56%56% 46%49%53% 37%34%	44%32%39% 20%37% 33% <sup>27</sup> %22%	19%23% 74% <sup>75%84</sup> % 19%	17% 26%40%84%75%
55% 49% 20% 27% 21% 15%	42% 44 763 76 26% 33% 43% 19% 15% 2	41% 50%	20% 35%42% <sup>94%0</sup> 98%
91% 70% 27% 20% 42% 24%	38% 25% 34% 45% 30% 36%	30% 44% 52% 29%	88% cov 20% 65%
62% <u>38%</u> 42% 52% 26% <u>31%</u> 36%	45% 23% 43% 26% 27% 8% 219	<sup>6</sup> 16% 27% 20% 55%	74% 61% 39% 57% 69%
21% 65% 42% 48% 24% 69%	62% 10% 34% 19% 19%	30% 30% 26%	29% 70% 34% 57%
24% 47% 29% 47% 40% 36% 33% 30%	3 21% 26% <sup>23</sup> % 21% 32% 40	% 49% 33 <mark>% 25</mark> % 65% 80	0% 83% 65% 43% 34%
44% 47% 36% 33% 57% 30% 24%	21% 33% 28% 24% 13% 37% 4	1% 37% 31% 40% 72%	720/ 740/ 520/
46% 74% 56% 43% 36% 34% 74% 36%	67% 59% 38% 22% 14% 309	<sup>% 33% 37%</sup> 44% 72% <sup>67</sup>	7% 73% 71% 53%
59% 59% 63% 74% 58% 74% 68% 81%	66% 54% 59% 59% <b>19% 1</b> 3%	67% 52% 46%	52% 58% 45% 40%
91% 72% 62% 65% 62%	54% 92%75% 50% 54% 34%	6 28% 20% 33% 30% 31%	41% 46% 62%
90% 92% 98% 92% 90% 03%	72% 76% 33% 31 84% 699	6 49% - 59% 40% 44% 59% 40%	70/ 490/ 510/ 600/
94% 95% 99% 100% 99% 91%	b 90% 92% 96% 83% 85%	6 51% 40% 43% 5. 6 48% 49% 45%	53 <sup>%</sup> 74% 67%
98% 98% 99% 100% 99% 82%	<sup>b</sup> 91% 94% <sup>99%</sup> 97% 99	<sup>6</sup> 72% 65% 69%	35% 65% 74%
99 <sup>9</sup> % 99% <sup>99%</sup> 100% 100% 94% <sup>98%</sup>	<sup>3</sup> 98% 93% <sup>92%</sup> <sub>88%</sub> 98% 75%	6 <sup>36%</sup> 46% 74% 41%	26% 12% 37%
99% 100% <sub>86%</sub> 97% 97 <mark>%</mark> 100%	<sup>b</sup> 99% 95% 90 <mark>%</mark> <sup>69%</sup> 100 <u>% 88%</u>	73% 45% 61% 72% 59%	37% 38% 34%
	044 12000		
0 250 500 km	8 - 20 % 20	- 40 % 🛄 40 - 60 % 🔲 66	) - 80 % 🔲 80 - 100 %

Figure 55  $OA_b$  for each tile of the static map in Africa based on the CCI Prototype

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The overall agreement of the static map in Africa is 66% with FROM-GLC and 57% with CCI Prototype (Table 69). The agreement with FROM-GLC increased by 22%. CCI Prototype was not used for inter-comparison in the first production, therefore it is not possible to compare the agreement of the first and second production.  $OA_b$  for individual tiles is showing higher agreement in the north and south of the region of interest (Figure 54 and Figure 55). This is probably due to the homogeneous Bareland landscape in the north, and the homogeneous Forest landscape in the south.

# 3.5.3.4 Per class benchmark accuracy with existing HRLCs

According to the agreement on the level of individual classes (Table 70), the classification of Water and Permanent water is "Excellent", and the classification of Bareland and Forest is "Well". Substantial improvement of agreement is achieved for Bareland and Forest classes.

Existing LC	Index	Bareland	Built-up	Cropland	Forest	Grassland	Permanent ice and snow	Shrubland	Water	Water permanent	Water seasonal	Wetland
FROM GLC		94%	22%	70%	98%	69%		31%	90%			39%
CCIPrototype		90%	61%	44%	60%	60%		24%	94%			13%
GSW seasonality										99%	20%	
FNF	PAb				57%				88%			
GHS BU S1			50%									
WSF			29%									
FROM GLC		85%	19%	44%	73%	48%		91%	98%			9%
CCIPrototype		70%	38%	65%	92%	35%		21%	93%			6%
GSW seasonality										97%	47%	
FNF	UAb				97%				93%			
GHS BU S1			21%									
WSF			54%									

Tahlo	70	ΠΔ.	and	DΔ.	for	the	whole	of	Africa
labic		Un	and		101	une	whole	01	Allica

# 3.6 HRLC historical maps – the second production

Historical maps in each region were delivered as a set of tiles. Table 71 contains details about the number of tiles per region for each historical product.

Table 71. Number of tiles for each historical product

Year	Region	Number of tiles	Region	Number of tiles	Region	Number of tiles
2019	Siberia	186	Amazon	234	Africa	280
2015	Siberia	186	Amazon	234	Africa	280
2010	Siberia	186	Amazon	234	Africa	280
2005	Siberia	186	Amazon	234	Africa	280
2000	Siberia	183	Amazon	234	Africa	280
1995	Siberia	174	Amazon	234	Africa	266
1990	Siberia	175	Amazon	234	Africa	263

From the point of view of benchmark accuracy, for binary maps that are specifically derived for a certain class – FNF, GHS BU S1, GHS BU LDS, GSW seasonality, Tree Cover, and WSF - OA<sub>b</sub> is very high due to the presence of the

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class that represents all the other classes but the one of interest for the map. Therefore,  $OA_b$  for these maps is not informative, and only  $PA_b$  and  $UA_b$  were taken into consideration for the following conclusions.

Unlike in the first production, in the second production, there were no two versions of GSW. The reason for this is explained in section 3.3.19. Furthermore, the GL30 map was not used for inter-comparison as explained in section 3.4.

In Siberia, there are only two existing land cover maps with multiple classes – FROM-GLC and ESA DUE GlobPermafrost. They are available for 3 inter-comparison years 2010, 2015, and 2019. This means that  $OA_b$  was estimated only in these years.  $OA_b$  was ranging from 45% to 69% depending on the year and dataset compared. On average, the agreement with FROM-GLC was around 62% for the 3 years in which this existing dataset is available, while with ESA DUE GlobPermafrost it is 45% for the 2019 comparison for which ESA DUE GlobPermafrost is available. The UA<sub>b</sub> and PA<sub>b</sub> of the Grassland class increased the most compared to the first production.

The overall agreement of the historical map with existing land cover maps in Amazon is varying from 57% to 74% depending on the year and dataset involved in inter-comparison. The best agreement is with the TerraClass dataset, whose values are higher on average than other datasets.

The agreement with each dataset was relatively homogeneous for different years. The agreement with MapBiomas – the only map available for all years concerned in the project - was around 63% for all the years. The agreement with TerraClass on average for all the years in which this dataset is available was around 73%, and with FROM-GLC around 64%. Agreement of CCI HRLC historical products with existing products for corresponding years increased compared to the first production. The classes for which the agreement increased the most are Built-up, Water, Water Permanent, and Cropland. The agreement for Grassland increased only in the period from 2010 onwards.

In the African region of interest, there are two multiple-class existing land cover maps – FROM-GLC and CCI Prototype. They are available for 3 inter-comparison years 2010, 2015, and 2019. Maximum OA<sub>b</sub> was with FROM-GLC for the 2019 comparison and it was 66%. The lowest OA<sub>b</sub> was with CCI Prototype for 2019 comparison – 46%. On average, agreement with FROM-GLC in 3 different years was 57%, while with CCI Prototype is only available for 2019 comparison and OA<sub>b</sub> is 46%. In comparison to the first production, increased UA<sub>b</sub> and PA<sub>b</sub> were observed for some years for classes Cropland and Bareland.

## 3.6.1 Siberia 2019

Following existing land cover maps are used for inter-comparison of historical products for 2019:

- FROM GLC 2017
- ESA DUE GlobPermafrost 2016
- WSF 2019
- GHS BU S1 2016
- FNF 2017
- GSW seasonality 2019

#### 3.6.1.1 Overall benchmark accuracy

There are two existing multiple-class land cover maps for the year 2019 - FROM-GLC and ESA DUE GlobPermafrost- with which historical product for the Siberia region was compared. Table 72 is showing the consistency between the historical map in Siberia and each of the existing land cover maps.

Existing dataset	OA <sub>b</sub>
FROM GLC	53%
ESA DUE GlobPermafrost	45%

Siberia results of OA<sub>b</sub> will be shown in form of maps for OA<sub>b</sub> with existing land cover available in the region. OA<sub>b</sub> concerning FROM-GLC is shown in Figure 56, and concerning ESA DUE GlobPermafrost in Figure 57.

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		87%	5			8	6%	32%	5	23%	
		49%	% 80% <sup>80%</sup>		7		6%	21%	2	775 695	
74%	71%	50%	Λ	52% 50%	55%	2096	1893 /	39%	74	<sup>36</sup> 695	
52%	36%	40%		61% 54%	15%	1693	14935	30%	8	26	
66%	41%	35%	5	0% 47%	1295	15%	1196	13%	207	6	
60%	68%	24%	52	% 64%	41%	13%	1196	6%	1683	200	
1895	1895	28%	504	% 62%	22%	26%	13%	895	15%	389	
24%	21%	24%	71%	6 47%	13%	20%	19%	30%	52%	649	
56%	39%	41%	48%	30%	22%	40%	34%	58%	79%	809	
58%	48%	38%	459	% 55%	46%	56%	63%	66%	82%	75%	
71%	72%	63%	48%	a 38%	40%	45%	68%	78%	8196	8195	
81968196	79%	67%	56%57	% 54%	52%	52%52%	74%	79%	8196 <sub>83%</sub>	83%	
87% 88%	81%	53%	60% 59	9% 51%	42%	44% 42%	67%	69%	<sup>73%</sup> 75%	84%	
35% 82%	77%	66%	57% 5	7% 56%	68%	84% 83%	67%	60%	68% 69%	94%	
6% 68%	72%	72%	76% 7	8% 80%	72%	76% 76%	76%	87%	84% 84%	84%	
201 560	61%	77%	7000	79%	82%	2007 7207	71%	79%	7504 7704	75%	

Figure 56. OA<sub>b</sub> for each tile of the 2019 historical map in Siberia based on FROM GLC



Figure 57. OA<sub>b</sub> for each tile of the 2019 historical map in Siberia based on ESA DUE GlobPermafrost
	Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>migh</b> resolution
<b>esa</b>	Issue	Date	Page	and cover
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According to FROM-GLC consistency with the historical map for 2019 is 53%, and according to ESA DUE GlobPermafrost is 45% (Table 72). Per tile  $OA_b$  (Figure 56, Figure 57) is showing very low values of  $OA_b$  (below 20%) in the North-East part of the region for both datasets – FROM-GLC and ESA DUE GlobPermafrost. According to the base map, the North-East landscape is similar to the North-West landscape. There is plenty of lakes/ponds surrounded by vegetation. However, in the North-East of the CCI HRLC vegetation is classified prevalently as Grassland, while in the North-West vegetation is detected as Lichens and Mosses. Therefore, probably Lichens and Mosses in the North-East regions were misclassified as Grassland in the historical product for 2019.

### 3.6.1.2 Per class benchmark accuracy

Classes Forest, and Water have  $UA_b$  and  $PA_b$  above 70 % thus the classification of these classes is "Well" (Table 73).

Dataset	Index	Bareland	Built-up	Cropland	Forest	Forest deciduous broadleaf	Forest evergreen needleleaf	Grassland	Lichens and Mosses	Permanent ice and snow	Shrubland	Shrubland evergreen	Water	Wetland
FROM GLC		56%	64%	1%	92%			44%	6%	0%	7%		97%	39%
ESA DUE GlobPermafrost		28%				22%	75%	77%	69%			0%	94%	38%
GHS BU S1	$PA_b$		0%											
WSF			85%											
FNF					86%								87%	
GSW seasonality													90%	
FROM GLC		13%	14%	0%	80%			33%	86%	0%	0%		83%	7%
ESA DUE GlobPermafrost		36%				24%	65%	15%	45%			68%	95%	12%
GHS BU S1	$UA_b$		100%											
WSF			6%											
FNF					68%								73%	
GSW seasonality													84%	

#### Table 73. UA<sub>b</sub> and PA<sub>b</sub> for the whole of 2019 Siberia

#### 3.6.2 Siberia 2015

Following existing land cover maps are used for inter-comparison of historical products for 2015:

- FROM GLC 2015
- GHS BU LDS 2014
- GSW seasonality 2015
- FNF 2015
- WSF 2015

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## 3.6.2.1 Overall benchmark accuracy

There is a single existing multiple-class land cover map for the year 2015 - FROM-GLC - with which historical product for the Siberia region was compared. Table 74 is showing the consistency between the historical map in Siberia and each of the existing land cover maps.

Table 74. Overal	l benchmark	accuracy fo	or the	whole	of Siberia	in	2015
------------------	-------------	-------------	--------	-------	------------	----	------

Existing dataset	OAb
FROM-GLC	69%

Siberia results of  $OA_b$  will be shown in form of maps for  $OA_b$  with existing land cover available in the region.  $OA_b$  concerning FROM-GLC is shown in Figure 58.



Figure 58.  $OA_{b}\xspace$  for each tile of the 2015 historical map in Siberia based on FROM-GLC

According to FROM-GLC consistency with the historical map for 2015 is 69% (Table 74) which is 16% more compared to the first production. In the second production, the most obvious improvement is in class Grassland for which UA<sub>b</sub> and PA<sub>b</sub> are more than 50%, which makes Grassland classification "Relatively good". There is also an increase of agreement in the class Forest by several percent. Per tile OA<sub>b</sub> (Figure 58) does not show very low values, but in the lower central part of the region, there are values from 40-60% that are clustered. In the CCI HRLC, the presence of Wetland classes is evident in this region, while in FROM-GLC it is Grassland. However, the base map is showing that the classification in CCI HRLC is likely to be correct because this area is rich with small water bodies, and thus Wetland is expected to be found.

### 3.6.2.2 Per class benchmark accuracy

Classes Forest, and Water have  $UA_b$  and  $PA_b$  above 70 % thus the classification of these classes is "Well" (Table 75).

Dataset	Index	Bareland	Built-up	Cropland	Forest	Grassland	Permanent ice and snow	Shrubland	Water	Wetland
FROM GLC	PA <sub>b</sub>	69%	86%	0%	79%	55%	0%	12%	95%	53%

Table 75. UA<sub>b</sub> and PA<sub>b</sub> for the whole of 2015 Siberia

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GHS			73%						99%	
WSF			73%							
FNF					85%				91%	
GSW seasonality									88%	
FROM GLC		5%	3%	0%	79%	91%	0%	2%	82%	1%
GHS			11%						74%	
WSF	UAb		19%							
FNF					60%				71%	
GSW seasonality									84%	

### 3.6.3 Siberia 2010

Following existing land cover maps are used for inter-comparison of historical products for 2010:

- FROM GLC 2010
- GUF 2011
- GSW seasonality 2010
- FNF 2010

### 3.6.3.1 Overall benchmark accuracy

There is a single existing multiple-class land cover map for the year 2010 with which the historical product for the Siberia region was compared: FROM-GLC. Table 76 is showing the consistency between the historical map in Siberia and each of the existing land cover maps.

Table 76. Overall benchmark accurac	y for the whole of Si	beria in 2010
-------------------------------------	-----------------------	---------------

Existing dataset	OAb
FROM-GLC	63%

Siberia results of  $OA_b$  will be shown in form of maps for  $OA_b$  with each of the two existing land covers available in the region.  $OA_b$  concerning FROM-GLC is shown in Figure 59.



Figure 59. OA<sub>b</sub> for each tile of the 2010 historical map in Siberia based on FROM GLC

According to FROM-GLC consistency with the historical map for 2010 is 63%, which is a 10% increase in agreement compared to the first production (Table 76). Per tile  $OA_b$  (Figure 59) is relatively consistent with per

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tile  $OA_b$  for 2015. Therefore, the lower agreement is probably because Wetland is classified as Grassland in FROM -GLC.

### 3.6.3.2 Per class benchmark accuracy

Classes Forest, and Water have UA<sub>b</sub> and PA<sub>b</sub> above 70 % thus the classification of these classes is "Well" (Table 77). In the second production, UA<sub>b</sub> and PA<sub>b</sub> increased by over 50%, which makes the Grassland classification "Relatively good", but there is also a small improvement in the agreement for the Forest class as well.

Dataset	Index	Bareland	Built-up	Cropland	Forest	Grassland	Permanent ice and snow	Shrubland	Water	Wetland
FROM GLC		6%	13%	0%	74%	57%	0%	12%	86%	36%
GUF			77%							
FNF	$PA_{b}$				91%				89%	
GSW seasonality									95%	
FROM GLC		14%	25%	1%	73%	77%	0%	2%	79%	1%
GUF			17%							
FNF	$UA_{b}$				63%				75%	
GSW seasonality									80%	



#### 3.6.4 Siberia 2005

Following existing land cover maps are used for inter-comparison of historical products for 2005:

- FNF 2007
- GSW seasonality 2005

#### 3.6.4.1 Overall benchmark accuracy

For the year 2005 other multiple-class land covers do not exist, therefore OA<sub>b</sub> cannot be reported.

### 3.6.4.2 Per class benchmark accuracy

When the agreement of individual classes is concerned, there is a "Well" agreement for the class of Water and "Relatively good" for Forest (Table 78).

Dataset	Index	Forest	Water
FNF	DA	91%	94%
GSW seasonality			94%
FNF	114	63%	72%
GSW seasonality	UAb		79%

Table 78. UA $_{b}\,and\,PA_{b}\,for$  the whole of 2005 Siberia

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### 3.6.5 Siberia 2000

Following existing land cover maps are used for inter-comparison of historical products for 2000:

- GHS BU LDS 2000
- TreeCover 2000
- GSW seasonality 2000

#### 3.6.5.1 Overall benchmark accuracy

For the year 2005 other multiple-class land covers do not exist, therefore OA<sub>b</sub> cannot be reported.

### 3.6.5.2 Per class benchmark accuracy

Binary datasets show the agreement of some classes. There is a well agreement for classes of Water, and Forest (Table 79).

Dataset	Index	Built-up	Forest	Water
GHS		75%		99%
GSW seasonality	$PA_b$			93%
TreeCover			92%	
GHS		15%		74%
GSW seasonality	$UA_b$			81%
TreeCover			70%	

Table 79. UA <sub>b</sub> and F	PA <sub>b</sub> for th	e whole of	2000 Siberia
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### 3.6.6 Siberia 1995

Following existing land cover maps are used for inter-comparison of historical products for 1995:

• GSW seasonality 1994

#### 3.6.6.1 Overall benchmark accuracy

For the year 1995 other multiple-class land covers do not exist, therefore OA<sub>b</sub> cannot be reported.

#### 3.6.6.2 Per class benchmark accuracy

For the class agreement, GSW seasonality is showing high scores for the Water class thus this class can be considered as "Well" classified (Table 80).

Existing LC	Index	Water
GSW seasonality	$PA_b$	89%
GSW seasonality	UA <sub>b</sub>	84%

# Table 80. UA<sub>b</sub> and PA<sub>b</sub> for the whole of 1995 Siberia

#### 3.6.7 Siberia 1990

Following existing land cover maps are used for inter-comparison of historical products for 1990:

- GHS BU LDS 1990
- GSW seasonality 1990

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### 3.6.7.1 Overall benchmark accuracy

For the year 1990 other multiple-class land covers do not exist, therefore OA<sub>b</sub> cannot be reported.

#### 3.6.7.2 Per class benchmark accuracy

For the class agreement, GSW seasonality and GHS BU LDS are showing high scores Water class thus this class can be considered as "Well" classified (Table 81).

Dataset	Index	Built-up	Water
GHS		74%	99%
GSW seasonality	PAb		88%
GHS	114	17%	74%
GSW seasonality	UAb		84%

Table 8	31.	UA	and	РАь	for	the	whole	of	1990	Siberia
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#### 3.6.8 Amazon 2019

Following existing land cover maps are used for inter-comparison of historical products for 2019:

- FROM GLC 2017
- MapBiomas 2019
- GHS BU S1 2016
- WSF 2019
- FNF 2017
- GSW seasonality 2019

#### 3.6.8.1 Overall benchmark accuracy

There are two existing multiple-class land cover maps for the year 2019 - FROM-GLC, and MapBiomas - with which historical product for the Amazon region was compared. Table 82 is showing the consistency between the historical map for the Amazon and each of the existing land cover maps.

Existing dataset	OA <sub>b</sub>
FROM GLC	71%
MapBiomas	63%

Amazon results of OA<sub>b</sub> will be shown in form of maps for OA<sub>b</sub> with existing land cover available in the region. OA<sub>b</sub> concerning FROM-GLC is shown in Figure 60, and concerning MapBiomas in Figure 61.

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Figure 60. OA<sub>b</sub> for each tile of the 2019 historical map in Amazon based on FROM GLC



Figure 61. OA<sub>b</sub> for each tile of the 2019 historical map in Amazon based on MapBiomas

According to FROM-GLC consistency with a historical map for 2019 is 71%, and according to MapBiomas is 63% (Table 82). Per tile  $OA_b$  (Figure 60, Figure 61) is not showing any specific pattern of  $OA_b$  except higher values in the northern area of the region of interest where homogeneous areas of forest are present.

### 3.6.8.2 Per class benchmark accuracy

When classes are concerned, the Permanent Water classification is "Excellent". Forest, Water, and Grassland have UA<sub>b</sub> and PA<sub>b</sub> above 70 %, thus the classification of these classes is "Well". The Built-up class has PA<sub>b</sub> above 50 % with all existing HRLCs, and UA<sub>b</sub> above 50 % with the majority of existing HRLCs therefore it can be considered "Relatively good" (Table 83).

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Dataset	Index	Bareland	Built-up	Cropland	Forest	Grassland	Shrubland	Water	Water permanent	Water seasonal	Wetland	Wetland Herbaceous	Wetland Shrubby
FROM GLC		61%	68%	81%	90%	76%	14%	83%			50%		
MapBiomas		19%	71%	23%	91%	84%	16%	69%				11%	0%
GHS BU S1			80%										
WSF	PAb		84%										
FNF					82%			25%					
GSW seasonality									89%	9%			
FROM GLC		2%	54%	68%	76%	72%	44%	89%			36%		
MapBiomas		10%	69%	37%	64%	68%	46%	94%				34%	0%
GHS BU S1			41%										
WSF	UAb		39%										
FNF					74%			66%					
GSW seasonality									91%	21%			

### 3.6.9 Amazon 2015

Following existing land cover maps are used for inter-comparison of historical products for 2015:

- FROM GLC 2015
- MapBiomas 2015
- TerraClass 2014
- GHS 2014
- WSF 2015
- FNF 2015
- AUE Sao Paulo 2014, Ribeirao Preto 2014

#### 3.6.9.1 Overall benchmark accuracy

There are three existing multiple-class land cover maps for the year 2015 - FROM-GLC, MapBiomas, and TerraClass - with which historical product for the Amazon region was compared. Table 84 is showing the consistency between the historical map for Amazon and each of the existing land cover maps.

Table 84. Overall benchmark accuracy	y for the whole of Amazon in 2015
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Existing dataset	OA <sub>b</sub>
FROM GLC	66%
MapBiomas	71%
TerraClass	73%

Amazon results of  $OA_b$  will be shown in form of maps for  $OA_b$  with existing land cover available in the region.  $OA_b$  concerning FROM-GLC is shown in Figure 62, concerning the MapBiomas in Figure 63, and concerning the TerraClass in Figure 64.

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Figure 62. OA<sub>b</sub> for each tile of the 2015 historical map in Amazon based on FROM-GLC



Figure 63. OA<sub>b</sub> for each tile of the 2015 historical map in Amazon based on MapBiomas

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Figure 64. OA<sub>b</sub> for each tile of the 2015 historical map in Amazon based on TerraClass

For the year 2015 OA<sub>b</sub> was 66% for FROM-GLC, 71% for MapBiomas, and 73% for TerraClass (Table 84). Compared to the first production, this is an increase of agreement of 9% for inter-comparison with FROM-GLC, 14% with MapBiomas, and 10% with Terra Class. The per tile OA<sub>b</sub> for FROM-GLC, MapBiomas, and TerraClass are relatively homogeneous (Figure 62, Figure 63, Figure 64). Higher values are evident in the northern part of the area of interest where a homogeneous forest landscape is present. OA<sub>b</sub> with FROM-GLC has some lower values in the south-west part where CCI HRLC detected Cropland surrounded by deciduous broadleaf forest, while this is Grassland in FROM-GLC. Basemap is showing that the CCI HRLC classification is correct.

### 3.6.9.2 Per class benchmark accuracy

Regarding the class accuracy (Table 85) Forest, Water, Permanent water, and Grassland are considered as "Well" classified, while Built-up is classified as "Relatively good". Compared to the first production, improvements are evident for Grassland, Cropland, and Built-up classes. Agreement with the AUE dataset is consistent with the agreement with other existing datasets regarding the Built-up class.

Dataset	Index	Bareland	Built-up	Cropland	Forest	Grassland	Shrubland	Water	Water permanent	Water seasonal	Wetland	Wetland Herbaceous
FROM GLC		30%	77%	63%	89%	69%	12%	79%			50%	
MapBiomas		21%	77%	76%	90%	79%	18%	73%				42%
TerraClass		0%	2%	82%	95%	63%	7%	59%				
GHS	$PA_b$		87%					92%				
WSF			73%									
FNF					83%			30%				
GSW seasonality									87%	9%		
FROM GLC		5%	59%	68%	71%	68%	30%	89%			14%	
MapBiomas	114	10%	77%	66%	69%	79%	44%	91%				37%
TerraClass	UAb	2%	69%	63%	75%	83%	16%	73%				
GHS			45%					53%				

Table 85. UA $_{b}$  and PA $_{b}$  for the whole of 2015 Amazon

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WSF			72%							
FNF					72%		72%			
GSW seasonality								89%	19%	
AUE Ribeirao Preto	DA.		83%				29%			
	PAb	(		· · · ·	(					
AUE São Paulo	۱ <u> </u>		83%		۱ 		61%			
AUE Ribeirao Preto	114.	 	83% 68%		 		61% 26%			

#### 3.6.10 Amazon 2010

Following existing land cover maps are used for inter-comparison of historical products for 2010:

- FROM GLC 2010
- MapBiomas 2010
- TerraClass 2010
- GUF 2011
- FNF 2010
- GSW seasonality 2010

### 3.6.10.1 Overall benchmark accuracy

There are three existing multiple-class land cover maps for the year 2010 with which the historical product for the Amazon region was compared: FROM-GLC, MapBiomas, and TerraClass. Table 86 is showing the consistency between the historical map for the Amazon and each of the existing land cover maps.

Existing dataset	OA <sub>b</sub>
FROM GLC	57%
MapBiomas	67%
TerraClass	71%

Amazon results of  $OA_b$  will be shown in form of maps for  $OA_b$  with each of the two existing land covers available in the region.  $OA_b$  concerning FROM-GLC is shown in Figure 65, Mapbiomas in Figure 66, and concerning TerraClass in Figure 67.

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Figure 65.  $OA_{\mbox{\tiny b}}$  for each tile of the 2010 historical map in Amazon based on FROM GLC



Figure 66. OA<sub>b</sub> for each tile of the 2010 historical map in Amazon based on MapBiomas

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Figure 67. OA<sub>b</sub> for each tile of the 2010 historical map in Amazon based on TerraClass

For the year 2010 OA<sub>b</sub> was 57% for FROM-GLC, 67% for MapBiomas, and 71% for TerraClass (Table 86). Compared to the first production, this is an increase of 11% for inter-comparison with FROM-GLC, 16% with MapBiomas, and 4% with Terra Class. The per-tile OA<sub>b</sub> does not show a particular pattern for MapBiomas and TerraClass (Figure 66 and Figure 67). OA<sub>b</sub> with FROM-GLC has some lower values in the south-west part where CCI HRLC detected Cropland surrounded by deciduous broadleaf forest, while this is Grassland in FROM-GLC. Basemap is showing that the CCI HRLC classification is correct.

### 3.6.10.2 Per class benchmark accuracy

Regarding class accuracy (Table 87), Forest and Water permanent are "Well" classified, and Cropland, Grassland, and Built-up are "Relatively good" classified. Unlike for other years, many PA<sub>b</sub> values for the Water class are below 50% which indicates an underestimation of the Water class for this year. The most significant agreement increase concerning the first production is for the Built-up, Cropland, Grassland, Water, and Water permanent classes.

Dataset	Index	Bareland	Built-up	Cropland	Forest	Grassland	Shrubland	Water	Water permanent	Water seasonal	Wetland	Wetland Herbaceous
FROM GLC		2%	57%	48%	77%	58%	8%	41%			38%	
MapBiomas		21%	77%	75%	91%	72%	15%	70%				48%
TerraClass	D۸	1%	40%	76%	96%	56%	9%	9%				
GUF	PAb		76%									
FNF					87%			20%				
GSW seasonality									84%	5%		
FROM GLC		6%	22%	57%	70%	52%	13%	87%			9%	
MapBiomas		6%	77%	52%	67%	79%	38%	91%				37%
TerraClass	UA <sub>b</sub>	1%	67%	59%	74%	81%	16%	75%				
GUF			65%									
FNF					75%			7%				

Table 8	7. U	Ahan		for	the	whole	of	2010	Amazon
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	Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>migh</b> resolution
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GSW seasonality			89	9% 15%

### 3.6.11 Amazon 2005

Following existing land cover maps are used for inter-comparison of historical products for 2005:

- MapBiomas 2005
- TerraClass 2004
- FNF 2007
- GSW seasonality 2005

#### 3.6.11.1 Overall benchmark accuracy

There are 2 existing multiple-class land cover maps for the year 2005 with which the historical product for the Amazon region was compared: MapBiomas and TerraClass. Table 88 is showing the consistency between the historical map for the Amazon and each of the existing land cover maps.

Table 88. Overall benchmark accuracy for the whole of Amazon in 2005

Existing dataset	OA <sub>b</sub>
MapBiomas	65%
TerraClass	74%

Amazon results of OA<sub>b</sub> will be shown in form of maps for OA<sub>b</sub> with each of the two existing land covers available in the region. OA<sub>b</sub> concerning MapBiomas is shown in Figure 68, and concerning TerraClass in Figure 69.



Figure 68.  $OA_{\mbox{\tiny b}}$  for each tile of the 2005 historical map in Amazon based on MapBiomas

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Figure 69.  $OA_{\mbox{\tiny b}}$  for each tile of the 2005 historical map in Amazon based on TerraClass

For the year 2005  $OA_b OA_b$  was 65% for MapBiomas, and 74% for TerraClass (Table 88). Compared to the first production, this is an increase of agreement of 10% for inter-comparison with MapBiomas and a decrease of the agreement by 1% with Terra Class. The per-tile  $OA_b$  does not show a particular pattern for MapBiomas and TerraClass (Figure 68 and Figure 69).

## 3.6.11.2 Per class benchmark accuracy

Regarding class accuracy (Table 89) Forest and Permanent water are "Well" classified, while Grassland and Water are considered "Relatively good". In comparison to the first production, improvement in agreement for Water is significant.

Dataset	Index	Bareland	Built-up	Cropland	Forest	Grassland	Shrubland	Water	Water permanent	Water seasonal	Wetland Herbaceous
MapBiomas		17%	77%	74%	91%	68%	14%	71%			55%
TerraClass	DA.	1%	2%	81%	95%	48%	9%	60%			
FNF	ΓAb				88%			38%			
GSW seasonality									82%	7%	
MapBiomas		7%	77%	47%	66%	79%	33%	90%			41%
TerraClass	114.	2%	76%	38%	84%	79%	8%	71%			
FNF	UAb				73%			66%			
GSW seasonality									89%	14%	



#### 3.6.12 Amazon 2000

Following existing land cover maps are used for inter-comparison of historical products for 2000:

- MapBiomas 2000
- GHS 2000
- GSW seasonality 2000
- TreeCover 2000

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• AUE - Sao Paulo 2000, Ribeirao Preto 2001

### 3.6.12.1 Overall benchmark accuracy

There is a single multiple-class land cover map for the year 2000 – MapBiomas - with which the historical product for the Amazon region was compared. Table 90 is showing the consistency between the historical map of the Amazon and each of the existing land cover maps.

Table 90. Overall benchmark accuracy for the whole of Amazon in 2000

Existing dataset	OAb
MapBiomas	62%

Amazon results of  $OA_b$  will be shown in form of maps for  $OA_b$  with existing land cover available in the region.  $OA_b$  concerning MapBiomas in Figure 70.



Figure 70. OA<sub>b</sub> for each tile of the 2000 historical map in Amazon based on MapBiomas

The only existing multiple-class land cover map for 2000 is MapBiomas.  $OA_b$  for this map for this year was 62% (Table 90) which is a 12% of improvement in agreement compared to the first production. The per-tile  $OA_b$  is not subject to a distinct pattern (Figure 70).

### 3.6.12.2 Per class benchmark accuracy

Regarding class accuracy (Table 91), Built-up, Forest, Grassland, Water, and Water permanent are "Well" classified. The most significant improvements in the agreement are for the classes Built-up, Water, Permanent Water, and Cropland. Agreement of AUE increased compared to the first production, and it can be considered "Well". It is consistent with the agreement of other datasets related to the Built-up class.

Dataset	Index	Bareland	Built-up	Cropland	Forest	Grassland	Shrubland	Water	Water bermanent	Water seasonal	Wetland	Wetland Herbaceous
MapBiomas		16%	72%	73%	93%	65%	11%	72%				54%
GHS	п۸		77%					93%				
GSW seasonality	PAb								85%	6%		
TreeCover					93%							

Table 91. UA<sub>b</sub> and PA<sub>b</sub> for the whole 2000 Amazon

Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>migh</b> resolution
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MapBiomas		10%	82%	37%	62%	79%	34%	88%			42%
GHS			58%					59%			
GSW seasonality	UAb								86%	14%	
TreeCover					78%						
AUE Ribeirao Preto			91%					0%			
AUE Ribeirao Preto AUE Sao Paulo	PA <sub>b</sub>		91% 93%					0% 41%			
AUE Ribeirao Preto AUE Sao Paulo AUE Ribeirao Preto	PAb		91% 93% 70%					0% 41% 6%			

#### 3.6.13 Amazon 1995

Following existing land cover maps are used for inter-comparison of historical products for 1995:

- MapBiomas 1995
- GSW seasonality 1995

#### 3.6.13.1 Overall benchmark accuracy

There is a single existing multiple-class land cover map for the year 1995 – MapBiomas - with which historical product for the Amazon region was compared. Table 92 is showing the consistency between the historical map of the Amazon and the existing land cover map.

#### Table 92. Overall benchmark accuracy for the whole of Amazon in 1995

Existing dataset	OA <sub>b</sub>
MapBiomas	61%

Amazon results of  $OA_b$  will be shown in form of maps for  $OA_b$  with existing land cover available in the region.  $OA_b$  concerning MapBiomas is shown in Figure 71.



#### Figure 71. OA<sub>b</sub> for each tile of the 1995 historical map in Amazon based on MapBiomas

The only existing multiple-class land cover map for 1995 is MapBiomas (Table 92). It is showing 61% of consistency with the historical map for 1995 in Amazon. It is a 5% of improvement in consistency concerning the first production. The per-tile  $OA_b$  does not show a particular pattern for MapBiomas (Figure 71).

#### 3.6.13.2 Per class benchmark accuracy

It shows "Well" agreement for Built-up, Forest, Water, and Permanent water classes. The Grassland class is "Relatively good" classified (Table 93). In comparison to the first production, significant improvements in agreement for Built-up, Water, and Permanent Water are visible.

Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>mage</b> high resolution
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Table 93. UA<sub>b</sub> and PA<sub>b</sub> for the whole of 1995 Amazon

Dataset	Index	Bareland	Built-up	Cropland	Forest	Grassland	Shrubland	Water	Water permanent	Water seasonal	Wetland Herbaceous
MapBiomas	D۸	11%	67%	68%	93%	62%	12%	65%			47%
GSW seasonality	PAb								70%	3%	
MapBiomas	114.	9%	83%	31%	63%	76%	38%	86%			39%
GSW seasonality	UAb								86%	10%	

### 3.6.14 Amazon 1990

Following existing land cover maps are used for inter-comparison of historical products for 1990:

- MapBiomas 1990
- GHS 1990
- GSW seasonality 1990
- AUE Sao Paulo 1988, Ribeirao Preto 1990

#### 3.6.14.1 Overall benchmark accuracy

There is a single existing multiple-class land cover map for the year 1990 – MapBiomas - with which historical product for the Amazon region was compared. Table 94 is showing the consistency between the historical map of the Amazon and the existing land cover map.

Existing dataset	OA <sub>b</sub>
MapBiomas	58%

Amazon results of  $OA_b$  will be shown in form of maps for  $OA_b$  with existing land cover available in the region.  $OA_b$  concerning MapBiomas is shown in Figure 72.



Figure 72. OA<sub>b</sub> for each tile of the 1990 historical map in Amazon based on MapBiomas

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The only existing multiple-class land cover map for 1990 is MapBiomas (Table 94). It is showing 58% of consistency with the historical map for 1990 in Amazon, which is a 2% of improvement in consistency compared to the first production.

### 3.6.14.2 Per class benchmark accuracy

The per-tile OA<sub>b</sub> does not show a particular pattern for MapBiomas (Figure 72). It shows "Well" agreement for Forest, Water, and Permanent Water classes, and "Relatively good" agreement for Built-up and Grassland classes (Table 95). In comparison to the first production, improvements in agreement for Built-up, Water, and Permanent Water classes are significant. Agreement with AUE increased compared to the first production, and it can be considered "Well". It is a bit higher than agreement with other existing datasets related to the Built-up class. Given that the AUE dataset is focused on big cities (Ribeirao Preto and Sao Paolo), it may indicate that classification of the Built-up class is more successful in cities than Built-up elsewhere. It might be due to the homogeneity of Built-up classes in cities.

Dataset	Index	Bareland	Built-up	Cropland	Forest	Grassland	Shrubland	Water	Water permanent	Water seasonal	Wetland Herbaceous
MapBiomas		9%	68%	66%	93%	60%	10%	61%			46%
GHS	$PA_b$		73%					88%			
GSW seasonality									70%	5%	
MapBiomas		7%	73%	28%	60%	73%	39%	84%			39%
GHS	$UA_b$		51%					69%			
GSW seasonality									85%	11%	
AUE Ribeirao Preto	DA.		92%					0%			
AUE Sao Paulo	ΓAb		77%					5%			
AUE Ribeirao Preto	110.		72%					4%			
AUE Sao Paulo	UAb		74%					2%			

Table 95. UA<sub>b</sub> and PA<sub>b</sub> for the whole 1990 Amazon

#### 3.6.15 Africa 2019

Following existing land cover maps are used for inter-comparison of historical products for 2019:

- FROM GLC 2017
- CCI Prototype 2016
- GHS BU S1 2016
- WSF 2019
- FNF 2017
- GSW seasonality 2019

#### 3.6.15.1 Overall benchmark accuracy

There are two existing multiple-class land cover maps for the year 2019 - FROM-GLC, and CCI Prototype - with which historical product for the African region was compared. Table 96 is showing the consistency between the historical map in Africa and each of the existing land cover maps.

Table 96. Overall benchmark accuracy for the whole of Africa in 2019

Existing dataset	OAb
FROM GLC	66%

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### CCI Prototype

Africa results of OA<sub>b</sub> will be shown in form of maps for OA<sub>b</sub> with existing land cover available in the region. OA<sub>b</sub> concerning FROM-GLC is shown in Figure 73, and concerning CCI Prototype in Figure 74.

46%







Figure 74. OA<sub>b</sub> for each tile of the 2019 historical map in Africa based on the CCI Prototype

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According to FROM-GLC consistency with the historical map for 2019 is 66%, and according to CCI Prototype is 46% (Table 96). Per tile OA<sub>b</sub> with FROM-GLC (Figure 60) is not showing any specific pattern of OA<sub>b</sub> except higher values in the northern area of the region of interest where homogeneous areas of Bareland are present. On the opposite, per tile OA<sub>b</sub> with CCI Prototype Figure 61 shows a small number of grouped tiles with low OA<sub>b</sub> values. In those areas, confusion is between Forest in CCI Prototype and Shrubland in CCI HRLC. From a base map, the area seems to be prevalently covered with shrubs.

### 3.6.15.2 Per class benchmark accuracy

When classes are concerned, Permanent Water and Water classifications are "Excellent". Bareland and Cropland are "Relatively good" classified. It is surprising to observe that agreement with the Forest class is not high, since it was typically high in other regions.

Dataset	Index	Bareland	Built-up	Cropland	Forest	Grassland	Shrubland	Water	Water permanent	Water seasonal	Wetland
FROM GLC		91%	15%	71%	93%	66%	53%	87%			49%
CCIPrototype		92%	58%	48%	28%	45%	39%	97%			29%
GHS BU S1	DA.		50%								
WSF	ΓAb		27%								
FNF					23%			92%			
GSW seasonality									99%	24%	
FROM GLC		73%	17%	57%	47%	53%	89%	98%			10%
CCIPrototype	UA <sub>b</sub>	54%	45%	73%	80%	35%	24%	95%			12%
GHS BU S1			99%								
WSF			57%								
FNF					88%			93%			
GSW seasonality									98%	46%	

Table 97. UA<sub>b</sub> and PA<sub>b</sub> for the whole of 2019 Africa

#### 3.6.16 Africa 2015

Following existing land cover maps are used for inter-comparison of historical products for 2015:

- FROM GLC 2015
- GHS 2014
- WSF 2015
- FNF 2015
- GSW seasonality 2015

#### 3.6.16.1 Overall benchmark accuracy

There is one existing multiple-class land cover map for the year 2015 - FROM-GLC - with which historical product for the African region was compared. Table 98 is showing the consistency between the historical map in Africa and the existing land cover map.

Table 98. Overall benchmark accuracy for the whole of Africa in 2015

Existing dataset	OA <sub>b</sub>
FROM GLC	57%

Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>migh</b> resolution
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Africa results of  $OA_b$  will be shown in form of maps for  $OA_b$  with existing land cover available in the region.  $OA_b$  concerning FROM-GLC is shown in Figure 75.

96%	100%	100%	99%	99%	3 99%	97%	83%	82%	63%	54%	41%	54%	46%	43%	85%	99%	100%	99%	89%
80%	96%	96%	78%	59%	66%	91%	59%	47%	49%	25%	24%	21%	9 14926	39%	52%	96%	99%	99%	87%
58%	71%	77%	52%	69%	o 77%	<sup>9</sup> 74%	43%	44%	62%	24%	25%	) 20%	<sup>b</sup> 19%	39%	45%	86%	86%	94%	97%
19%	33%	8%	1493	26%	49%	60%	62%	86%	70%	59%	35%	19%	<sup>b</sup> 29%	35%	40%	73%	81%	83%	92%
15%	49%	17%	27%	51%	43%	42%	44%	81%	66%	39%	26%	42%	<sup>9</sup> 73%	44%	37%	54%	79%	83%	84%
1493	22%	23%	23%	26	%32%	38%	32%	42%	35%	52%	42	%46%	65%	46%	47%	37%	54%	82%	88%
25%	28%	28%	48%	35	%35%	42%	39%	24%	46%	64%	41	%45%	61%	56%	54%	45%	34%	50%	53%
34%	43%	40%	48%	33	%48%	57%	52%	51%	43%	41%	42	%38%	57%	56%	56%	42%	37%	34%	33%
55%	41%	15%	32%	42	% 52%	54%	63%	43%	45%	57%	53	% 42%	58%	65%	53%	42%	66%	80%	71%
83%	79%	51%	38%	40	% 45%	46%	57%	58%	62%	84%	66	% 55%	41%	53%	46%	67%	88%	73%	62%
80%	75%	75%	57%	39	% 42%	44%	56%	62%	55%	64%	55	% 47%	43%	49%	59%	72%	85%	48%	38%
64%	79%	76%	67%	66	% 51%	51%	63%	68%	60%	58%	57	% 49%	40%	26%	48%	91%	94%	81%	54%
72%	82%	71%	69%	62	% 63%	44%	54%	66%	69%	63%	53	% 50%	57%	64%	81%	93%	88%	44%	44%
71%	78%	77%	71%	52	% 48%	39%	49%	47%	61%	23%	65	% 41%	65%	73%	94%	95%	62%	27%	46%
0		250			500 k	m	OAb F	ROM G - 20 %	6LC 201	5 💻	20 -	40 % [	40	- 60 %	6	0 - 80 (	%	80 -	100 %

Figure 75.  $OA_{b}\xspace$  for each tile of the 2015 historical map in Africa based on FROM-GLC

Compared to the first production,  $OA_b$  increased by 11% for intercomparison with FROM-GLC.  $OA_b$  with FROM-GLC has higher values in the northern part of the area of interest where a homogeneous Bareland or Water landscape is present (Figure 75).

### 3.6.16.2 Per class benchmark accuracy

Regarding the class accuracy (Table 99) Water classification is "Excellent", while for the other classes the agreement is low, or there is just one dataset with a class used for inter-comparison, thus the conclusions cannot be made. However, the agreement regarding Bareland and Cropland of FROM-GLC increased compared to the first production.

Table 99.	UA <sub>b</sub> and	PA <sub>b</sub> for	the wh	ole of	2015	Africa
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Dataset	Index	Bareland	Built-up	Cropland	Forest	Grassland	Shrubland	Water	Water permanent	Water seasonal	Wetland
FROM GLC		90%	28%	61%	75%	54%	45%	83%			28%
GHS			74%					100%			
WSF	$PA_b$		40%								
FNF					22%			78%			
GSW seasonality									96%	40%	
FROM GLC	110	79%	53%	50%	55%	21%	84%	99%			11%
GHS	UAb		36%					95%			

Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>migh</b> resolution
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WSF		70%						
FNF			86%		92%			
GSW seasonality						99%	27%	

## 3.6.17 Africa 2010

Following existing land cover maps are used for inter-comparison of historical products for 2010:

- FROM GLC 2010
- GUF 2011
- FNF 2010
- GSW seasonality 2010

#### 3.6.17.1 Overall benchmark accuracy

There is one existing multiple-class land cover map for the year 2010 with which historical product for Africa region was compared - FROM-GLC. Table 100 is showing the consistency between the historical map in Africa and the existing land cover map.

Table 100. Overall benchmark accuracy for the whole of Africa in 2010

Existing dataset	OAb
FROM GLC	48%

Africa results of  $OA_b$  will be shown in form of maps for  $OA_b$  with existing land cover available in the region.  $OA_b$  concerning FROM-GLC is shown in Figure 76.



#### Figure 76. OA<sub>b</sub> for each tile of the 2010 historical map in Africa based on FROM GLC

For the year 2010  $OA_b$  was 48% for FROM-GLC (Table 100). Compared to the first production, this is a decrease of 5% for inter-comparison with FROM-GLC.  $OA_b$  with FROM-GLC has some very low values in the North-West part where Cropland and Grassland of CCI are mostly confused with Bareland of FROM-GLC. This is probably due to the overestimation of Bareland in the FROM-GLC because base map imagery shows some crop fields and sparse vegetation.

	Ref	CCI_HRLC_Ph	1-D4.1_PVIRa	<b>mage</b> high resolution
<b>esa</b>	Issue	Date	Page	and cover
	2.rev.1	01/02/2023	131	CCI

## 3.6.17.2 Per class benchmark accuracy

Regarding the class accuracy (Table 101), Water classification is "Excellent", while for the other classes the agreement is low, or there is just one dataset with a class used for inter-comparison, thus the conclusions cannot be made. However, the agreement regarding Cropland of FROM-GLC increased compared to the first production, while the agreement with Bareland decreased.

Dataset	Index	Bareland	Built-up	Cropland	Forest	Grassland	Shrubland	Water	Water permanent	Water seasonal	Wetland
FROM GLC		39%	13%	59%	47%	41%	55%	72%			20%
GL30		78%	21%	67%	49%	40%	37%	85%			25%
GUF	ΡΔь		36%								
FNF					26%			94%			
GSW seasonality									98%	28%	
FROM GLC		97%	39%	38%	69%	14%	55%	97%			2%
GL30		55%	73%	62%	57%	63%	17%	88%			24%
GUF	114		72%								
FNF					80%			92%			
GSW seasonality									99%	30%	

Table 101	IIA <sub>h</sub> and	PA <sub>b</sub> for	the	whole	of	2010	<b>Africa</b>
TADIC TOT	· Onpania		une	whole	U.	2010	Allica

### 3.6.18 Africa 2005

Following existing land cover maps are used for inter-comparison of historical products for 2005:

- FNF 2007
- GSW seasonality 2005

#### 3.6.18.1 Overall benchmark accuracy

For the year 2005 other multiple-class land covers do not exist for Africa, therefore OAb cannot be reported.

### 3.6.18.2 Per class benchmark accuracy

Regarding the class accuracy (Table 102) it is not possible to make strong conclusions given that for each class there is only one existing LC containing such a class, so the agreement refers to a specific map. According to FNF, the agreement with Water is "Well", and according to GSW seasonality, Permanent water is "Excellent".

Dataset	Index	Forest	Water	Water permanent	Water seasonal				
FNF	D۸.	24%	80%						
GSW seasonality	ΓAb			97%	32%				
FNF	114.	80%	93%						
GSW seasonality	UAb			99%	22%				

Table 102. UA <sub>b</sub> and PA <sub>b</sub> for	r the whole of 2005 Africa
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	Ref	CCI_HRLC_Ph	<b>Figh</b> resolution	
<b>esa</b>	Issue	Date	Page	and cover
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### 3.6.19 Africa 2000

Following existing land cover maps are used for inter-comparison of historical products for 2000:

- GHS 2000
- GSW seasonality 2000
- TreeCover 2000

#### 3.6.19.1 Overall benchmark accuracy

For the year 2000 other multiple-class land covers do not exist for Africa, therefore OAb cannot be reported.

### 3.6.19.2 Per class benchmark accuracy

Regarding the class accuracy (Table 103), it is not possible to make strong conclusions given that for each class there is only one existing LC containing such a class, so the agreement refers to a specific map. According to Tree cover, the agreement with the Forest is "Relatively good", according to GSW seasonality, Permanent water is "Excellent", and according to GHS Built-up is "Relatively good", and Water is "Excellent".

Dataset	Index	Bareland	Built-up	Cropland	Forest	Grassland	Shrubland	Water	Water permanent	Water seasonal	Wetland
GHS			72%					100%			
GSW seasonality									97%	28%	
TreeCover					71%						
GHS			58%					97%			
GSW seasonality									99%	36%	
TreeCover					54%						

Table 103. UA<sub>b</sub> and PA<sub>b</sub> for the whole of 2000 Africa

#### 3.6.20 Africa 1995

Following existing land cover maps are used for inter-comparison of historical products for 1995:

• GSW seasonality 1995

#### 3.6.20.1 Overall benchmark accuracy

For the year 1995 other multiple-class land covers do not exist for Africa, therefore OA<sub>b</sub> cannot be reported.

#### 3.6.20.2 Per class benchmark accuracy

For the class agreement (Table 104), GSW seasonality is showing "Excellent" agreement for the Permanent water class. Agreement of other classes cannot be estimated in absence of existing LC containing other classes.

Dataset	Index	Water permanent	Water seasonal
GSW seasonality	$PA_b$	97%	6%
GSW seasonality	UAb	97%	17%

Ref	CCI_HRLC_Ph	<b>migh</b> resolution	
Issue	Date	Page	and cover
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### 3.6.21 Africa 1990

Following existing land cover maps are used for inter-comparison of historical products for 1990:

- GHS 1990
- GSW seasonality 1990

### 3.6.21.1 Overall benchmark accuracy

For the year 1990 other multiple-class land covers do not exist for Africa, therefore OAb cannot be reported.

#### 3.6.21.2 Per class benchmark accuracy

Regarding the class accuracy (Table 105), it is not possible to make strong conclusions given that for each class there is only one existing LC containing such a class, so the agreement refers to a specific map. According to GSW seasonality, and according to GHS Water is "Excellent".

Dataset	Index	Built-up	Water	Water permanent	Water seasonal
GHS		70%	100%		
GSW seasonality	PA <sub>b</sub>			99%	0%
GHS		44%	97%		
GSW seasonality	UA <sub>b</sub>			100%	0%

Table 105. UA<sub>b</sub> and PA<sub>b</sub> for the whole of 1990 Africa

Cesa	Ref	CCI_HRLC_Ph	<b>Figh</b> resolution		
	Issue	Date	Page	and cover	
	2.rev.1	01/02/2023	134	CCI	

# 4 ANNEX 1 HRLC legend hierarchical approach



Figure 77. Hierarchical approach to determine the land cover class. The "Herbaceous vegetation aquatic or regularly flooded" corresponds to a vegetation cover more than 2 months per year, and a water persistence of more than 4 months. Finally, an herbaceous life form is present as apposed to a woody life form.