Potential of the Copernicus product “Riparian Zones” to map and monitor vegetation along streams and waterways

NIBIO REPORT | VOL. 10 | NO. 62 | 2024

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DATO/DATE:	RAPPORT NR./ REPORT NO.:	TILGJENGELIGHET/AVAILABILITY:	PROSJEKTNR./PROJECT NO.:	SAKSNR./ARCHIVE NO.:
06.05.2024	10/62/2024	Open	52153	21/00045

ISBN:	ISSN:	ANTALL SIDER/ NO. OF PAGES:	ANTALL VEDLEGG/ NO. OF APPENDICES:
978-82-17-03515-2	2464-1162	62	0

OPPDRAGSGIVER/EMPLOYER:	KONTAKTPERSON/CONTACT PERSON:
Norway Grants	Wendy Fjellstad

STIKKORD/KEYWORDS:	FAGOMRÅDE/FIELD OF WORK:
Vegetasjon langs bekker og vannveier, arealbruk	Kvalitetskontroll av satellitt-basert kart
Riparian Zones, land cover/land use	Remote sensing verification

SAMMENDRAG/SUMMARY:

Vegetasjon langs bekker og vannveier er viktig for biologisk mangfold, jordvern, erosjonskontroll, reduksjon av risiko for flom og tørke, og for elvens hydromorfologi. Copernicus Land Monitoring Service tilbyr geografiske produkter til støtte for forvaltning av land og vann. I denne rapporten analyserer vi potensialet til Riparian Zones temakart (RZ) for bruk til kartlegging og overvåking av vegetasjon langs bekker og vannveier i Norge og Polen. Vi inkluderer også analyser av temakartet Small Woody Features (SWF) innenfor områder kartlagt i RZ. Vi sammenlignet RZ med nasjonale data og flybilder for å verifisere kvaliteten til datasettet, både for status og endringer i arealdekke og arealbruk langs bekker og vannveier. Vi konkluderer med at den tematiske nøyaktigheten var ganske god for vann, jordbruksareal og skog, men at andre klasser ikke korresponderte like godt med de nasjonale dataene. Mange av avvikene kan skyldes forskjeller i klassifiseringssystemene, kildedatene og kartleggingsinstruksene for de forskjellige datasettene. I tillegg fant vi at den romlige oppløsningen av RZ er utilstrekkelig for detaljert overvåking, særlig i jordbrukslandskap. Likevel gir RZ en standardisert og harmonisert metodikk for hele Europa, og er et steg i riktig retning for å kunne overvåke arealdekke og arealbruk i disse dynamiske og viktige områdene.

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Innhold

1 Introduction

1.1 Background

Vegetation along streams and waterways is important, both for biodiversity, soil protection, erosion control, flood and drought risk reduction and for river hydromorphology (Gurnell 2014, Dufour et al. 2019). Changes in land use that affect riparian vegetation will therefore influence biodiversity, as well as potentially influencing both chemical and physical characteristics of streams and rivers. In addition, climate change is expected to affect the water cycle through changes in precipitation, river streamflow, and soil moisture dynamics (O' Keeffe et al. 2019). Changes both in land use and the climate thus present threats to groundwater, surface water, drinking water supplies, riverbank stability and to habitats and their biodiversity.

The Copernicus Land Monitoring Service (CLMS) provides geographical data and products to support land and water management. The CLMS has three components: Global, Pan-European and Local. The Pan-European component offers products dedicated to main land cover classes: Forests, Grassland, Imperviousness, Water and Wetness and Small Woody Features. The Local component offers a set of products dedicated to monitoring urban areas (Urban Atlas), land cover/land use in coastal zones, NATURA2000 and Riparian Zones.

In this report, we analyse the potential use of the Riparian Zones (RZ) products for mapping and monitoring vegetation along streams and waterways. We also include some analyses of the Small Woody Features (SWF) product within the Riparian Zones.

Riparian zones are not often explicitly mentioned or emphasized in environmental legislation. Nevertheless, they are clearly relevant in following up policies relating to biodiversity, water management and building and planning. Both Norway and Poland are bound by the European Water Framework Directive (WFD), Norway through the European Economic Agreement, and Poland as a member of the European Union. The Directive establishes a framework for the protection of all waters and aims to protect and enhance the status of water resources and promote sustainable water use based on long-term protection of water resources. As part of the Common Implementation Strategy of the WFD, guidance for monitoring (Anon 2003) focuses mainly on monitoring water quality. However, the structure and condition of riparian zones was defined as one of the hydro-morphological quality elements. Nevertheless, monitoring of riparian zones is not common and a harmonised methodology must be developed.

The CLMS product Riparian Zones is a step towards such monitoring but has not yet been widely tested and verified.

In Norway, the Water Resources Act aims to ensure socially proper use and management of river systems and groundwater. Chapter 2, section 11 describes general rules relating directly to riparian vegetation:

"Along the banks of river systems with a perennial flow, a limited natural belt of vegetation shall be maintained to counteract runoff and provide a habitat for plants and animals… The landowner, developer and affected authorities may require that the municipality stipulate the width of the belt. The width may also be stipulated in legally binding plans pursuant to the Planning and Building Act".

In Poland, the assessment of the vegetation as Green Infrastructure (GI) along streams and waterways is important for implementation of several EU strategies i.e. EU Strategy on Adaptation to Climate Change, the European Forests Strategy for 2030, the Common Agricultural Policy (CAP) objectives, Biodiversity strategy for 2023.

Systematic monitoring could help to ensure that this legislation is followed up. In addition, there is a need for an objective and harmonised approach to define the appropriate width of riparian zones in different contexts.

1.2 Objectives and scope

The main aim of this study was to examine the potential of the Copernicus Riparian Zones datasets for mapping and monitoring vegetation along streams and waterways in Poland and Norway to support policies. By comparing the Riparian Zones datasets with national datasets, we aimed to describe and understand their content, evaluate their accuracy, assess their relevance and usefulness for environmental monitoring and recommend potential improvements. We used existing national data and aerial imagery to verify the quality and the content of the RZ datasets, including land cover/land use changes within the riparian zones.

2 Datasets

2.1 CLMS Riparian Zones

The Riparian Zones (RZ) collection of datasets is a part of the Copernicus Land Service 'Local' component. The RZ products are designed to support the objectives of several European legal acts and policy initiatives, such as the EU Biodiversity Strategy to 2030, the Habitats and Birds Directives and the Water Framework Directive.

The CLMS define Riparian Zones as "transitional areas occurring between land and freshwater ecosystems, which are characterised by distinctive hydrology, soil and biotic conditions and strongly influenced by the stream water. These areas provide a wide range of riparian functions (e.g. chemical filtration, flood control, bank stabilization, aquatic life and riparian wildlife support) and ecosystem services".

The RZ collection includes two sets of status maps of Land Cover/Land Use (LC/LU) product for 2012 and 2018, one change product (RZ Land Cover/ Land Use Change 2012-2018), a Delineation of Riparian Zones product designed to set the extent of an Area of Interest for the collection and a Green Linear Elements product (reference year 2012) providing extra information as a supplement to the LC/LU data.

2.1.1 Riparian Zones Land Cover/Land Use product

The Riparian Zones Land Cover/Land Use (LC/LU) product represents a detailed land cover and land use dataset for areas along a variable buffer zone of selected rivers covering Europe for two reference years: 2012 and 2018. The metadata on the Copernicus webpage (updated 2021) states that the temporal extent of RZ_2012 was 2010 to 2014, whilst that of RZ_2018 was 2017 to 2018. However, in the Nomenclature guidelines (Tamame et al. 2021) more detailed information specifies the reference years for RZ_2012 as 2010-2013, and for RZ_2018 as 2017-2020. The Land Cover/Land Use classification is extracted from VHR satellite data and other available data e.g.: CLC 2012/2018; Urban Atlas 2012/2018; HR Layers Imperviousness Degree and Tree Cover Density. The technical documentation provides a list of image source data used without distinguishing which ones were used for which product (Tamame et al. 2021).

The Land Cover/Land Use product for the reference layer 2012 was acquired through computer assisted visual interpretation of data mainly derived from the DWH_MG2b_CORE_03 dataset (Optical VHR2 coverage over EU 2011-2013 and Riparian zones), mainly consisting of 1.5m VHR2 SPOT-6 and 2.5m VHR2 SPOT-5 HRG and 2m Pleiades satellite data (Riparian Zones, 2022). For the reference year 2018, the VHR_IMAGE_2018 dataset (Optical VHR coverage of EEA-39 2017-2019) was used, consisting of 2m Pleiades, Kompsat 3/3A, SuperView-1 and 4m SPOT-6/7, TripleSat, PlanetScope and Deimos satellite data. The dataset is a cloud-free VHR optical coverage acquired within predefined windows corresponding to the vegetation season in 2011-2012-2013 and 2017-2018-2019 respectively. The spatial accuracy of the RZ product is 2-4 m with positional accuracy less than 5 m (according to geo-location accuracy of satellite imagery delivered by ESA: less than 5 m RMSE) and spectral bands (for all selected missions) are: Blue, Green, Red, NIR. The results of classification were intersected with additional data (Urban Atlas 2012).

The data for RZ datasets are available from the Copernicus Land Monitoring Services at the following address: https://land.copernicus.eu/local/riparian-zones/riparian-zones-2018?tab=download. The data are divided into 43 European river basin districts (separate shapefiles). For Norway we used 7 districts, merged them, and then clipped to the extent of Norway. For Poland, we used 5 districts, merged and clipped them to the extent of Poland (Table 1).

Table 1. River basin districts covering Norway and Poland. Bold denotes districts that are primarily within the country, not bold denotes districts that fill in smaller parts along national borders.

Norway		Poland	
Name	*Catchments / regions*	**Name**	*Catchments / regions*
DU027A	*North Baltic, Skagerrak and Kattegat, South Baltic*	**DU007A**	*Dniestr, Pregolya, Vistula*
DU028A	*Glomma, Moere and Romsdal, Troendelag*	**DU015A**	*Danube_West*
DU030A	*Nordland, Troms*	**DU025A**	*Lielupe, Nemunas, Venta*
DU031A	*Bothnian Sea*	**DU032A**	*Elbe, Elbe coastal catchments*
DU034A	*Tornionjoki (Finnish part)*	**DU033A**	*Ucker*
DU036A	*SE South West, West Bay*		
DU037A	*Finnmark, Kemijoki, Teno, Nootom- and Paatsjoki (Finnish part)*		

The classification provides 55 distinct thematic classes divided into four levels of detail (Figure 1). The class definitions follow a pre-defined nomenclature based on the Mapping and Assessment of Ecosystems and their Services (MAES) typology of ecosystems and are further harmonised with Corine Land Cover and adapted to the specific characteristics of riparian zones (Figure 1).

Level 1	Level 2	Level 3	Level 4
1 Urban	1.1 Urban fabric, industrial, commercial, public, military and private units	1.1.1 Urban fabric (predominantly public and private units)	1.1.1.1 Continuous Urban Fabric (IM.D ≥ 80%)
			1.1.1.2 Dense Urban Fabric (IM.D ≥ 30-80%)
			1.1.1.3 Low Density Urban Fabric (IM.D < 30%)
		1.1.2 Industrial, commercial and military units	1.1.2.0
	1.2 Transport infrastructure	1.2.1 Road networks and associated land	1.2.1.0
		1.2.2 Railways and associated land	1.2.2.0
		1.2.3 Port areas and associated land	1.2.3.0
		1.2.4 Airports and associated land	1.2.4.0
	1.3 Mineral extraction, dump and construction sites, land without current use	1.3.1 Mineral extraction, dump and construction sites	1.3.1.0
		1.3.2 Land without current use	1.3.2.0
	1.4 Green urban, sports and leisure facilities	1.4.0	1.4.0.0
2 Cropland	2.1 Arable land	2.1.1 Arable irrigated and non-irrigated land	2.1.1.0
		2.1.2 Greenhouses	2.1.2.0
	2.2 Permanent crops	2.2.0	2.2.0.0
		2.2.1 Vineyards, fruit trees and berry plantations	2.2.1.0
		2.2.2 Olive groves	2.2.2.0
	2.3 Heterogeneous agricultural area	2.3.1 Annual crops associated with permanent crops	2.3.1.0
		2.3.2 Complex cultivation patterns	2.3.2.0
		2.3.3 Land principally occupied by agriculture with significant areas of natural vegetation	2.3.3.0
		2.3.4 Agro-forestry	2.3.4.0
3 Woodland and forest	3.0	3.0.0	3.0.0.0
	3.1 Broadleaved forest	3.1.1 Natural & semi-natural broadleaved forest	3.1.1.0
		3.1.2 Highly artificial broadleaved plantations	3.1.2.0
	3.2 Coniferous forest	3.2.1 Natural & semi-natural coniferous forest	3.2.1.0
		3.2.2 Highly artificial coniferous plantations	3.2.2.0
	3.3 Mixed forest	3.3.1 Natural & semi-natural mixed forest	3.3.1.0
		3.3.2 Highly artificial mixed plantations	3.3.2.0
	3.4 Transitional woodland and scrub	3.4.0	3.4.0.0
	3.5 Lines of trees and scrub	3.5.0	3.5.0.0
	3.6 Damaged forest	3.6.0	3.6.0.0
4 Grassland	4.0	4.0.0	4.0.0.0
	4.1 Managed grassland	4.1.0	4.1.0.0
	4.2 Natural & semi-natural grassland	4.2.1 Semi-natural grassland	4.2.1.0
		4.2.2 Alpine and sub-alpine natural grassland	4.2.2.0
5 Heathland and scrub	5.0	5.0.0	5.0.0.0
	5.1 Heathland and moorland	5.1.0	5.1.0.0
	5.2 Alpine scrub land	5.2.0	5.2.0.0
	5.3 Sclerophyllous scrubs	5.3.0	5.3.0.0
6 Open spaces with little or no vegetation	6.0	6.0.0	6.0.0.0
	6.1 Sparsely vegetated areas	6.1.0	6.1.0.0
	6.2 Beaches, dunes, river banks	6.2.1 Beaches and dunes	6.2.1.0
		6.2.2 River banks	6.2.2.0
	6.3 Bare rocks, burnt areas, glaciers and perpetual snow	6.3.1 Bare rocks, outcrops, cliffs	6.3.1.0
		6.3.2 Burnt areas (except burnt forest)	6.3.2.0
		6.3.3 Glaciers and perpetual snow	6.3.3.0
7 Wetland	7.0	7.0.0	7.0.0.0
	7.1 Inland wetlands	7.1.1 Inland marshes	7.1.1.0
		7.1.2 Peat bogs	7.1.2.1 Exploited peat bogs
			7.1.2.2 Unexploited peat bogs
	7.2 Coastal wetlands	7.2.1 Salt marshes	7.2.1.0
		7.2.2 Salines	7.2.2.0
		7.2.3 Intertidal flats	7.2.3.0
8 Water	8.0	8.0.0	8.0.0.0
	8.1 Water courses	8.1.1 Natural & semi-natural water courses	8.1.1.0
		8.1.2 Highly modified water courses and canals	8.1.2.0
		8.1.3 Seasonally connected water courses (oxbows)	8.1.3.0
	8.2 Lakes and reservoirs	8.2.1 Natural lakes	8.2.1.0
		8.2.2 Reservoirs	8.2.2.0
		8.2.3 Aquaculture ponds	8.2.3.0
		8.2.4 Standing water bodies of extractive industrial sites	8.2.4.0
	8.3 Transitional waters	8.3.1 Lagoons	8.3.1.0
		8.3.2 Estuaries	8.3.2.0
	8.4 Sea and ocean	8.4.0	8.4.0.0

Figure 1: Detailed Nomenclature for the LC/LU dataset of Riparian Zones (version 1.4.1, dated 2021.04.07) (source: RZ Nomenclature Guideline)

Table 2 summarizes the area of Riparian Zones 2018 by level 1 classes for Poland and Norway. For Poland, the largest area was occupied by the grassland class (11 004 km²), followed by cropland (9 834 km²) and woodland and forest (7 674 km²). The smallest classes were open spaces with little or no vegetation (45 km²) and heathland and scrub (11 km²). For Norway, the largest class was woodland and forest (16 175 km²), followed by water (10 877 km²) and heathland and scrub (4 126 km²). The smallest classes in Norway were urban (1 047 km²) and grassland (544 km²).

Table 2. Summary of occupied area of Riparian Zones 2018 classes (1st level of detail) for Poland and Norway.

Riparian Zones 2018 classes		Poland		Norway	
		Area (km²)	Percentage	Area (km²)	Percentage
1.	Urban	3 195.1	8.8	1 047.0	2.6
2.	Cropland	9 834.2	27.1	2 499.1	6.2
3.	Woodland and forest	7 674.2	21.2	16 175.2	40.3
4.	Grassland	11 003.9	30.3	544.6	1.4
5.	Heathland and scrub	11.4	0.0	4 126.1	10.3
6.	Open spaces with little or no vegetation	44.8	0.1	2 382.4	5.9
7.	Wetland	1 128.3	3.1	2 534.6	6.3
8.	Water	3 364.9	9.3	10 877.3	27.1
	Total	36 256.8		40 186.2	

2.1.2 Delineation of Riparian Zones product

The **Delineation of Riparian Zones (DRZ)** product is composed of three layers: actual, observable and potential RZ. This product is available in both vector and raster format, while vector is derived from the raster data. The CLMS specification (Weissteiner et al. 2016) documents the content and methodology for the three layers.

Following the data description available from the Copernicus webpage the Actual Riparian Zone (ARZ) is a combination of the Potential and the Observed Riparian Zone products. It expresses the probability to find riparian zones on the ground. Spatial modelling is based on four pillars: a) stratification of input data, to determine membership functions, b) calculation of the Potential Riparian Zone, c) calculation of the Observable Riparian Zone, and d) final aggregation to derive the Actual Riparian Zone Layer, which is located completely inside the Potential Riparian Zone. The temporal reference is 2010-2014.

The **Observable Riparian Zone (ORZ)** shows the observed extent of riparian features (often riparian vegetation, but also including e.g. riverbanks). Spatial Modelling of the Observable Riparian Zone is based on layers of vegetation, water, soil and built-up observations based on remote sensing data and a very detailed LC/LU classification. Additionally, indicators for vegetation wetness, vegetation vigour and leaf water content provide evidence of riparian features. All relevant datasets are included in a segmentation approach and the resulting membership degrees of all datasets are combined to a single membership degree expressing the probability to encounter riparian features on ground. The source data include the Riparian Zone LC/LU product supplemented with NDVI and NDWI derived from Landsat-8 data from 2013/2014. The temporal reference is 2010-2014.

Delineation of **Potential Riparian Zones (PRZ)** is a modelled area with a high probability to host riparian features. It is based on EU-scale DEM (25 m resolution), water mask from several pan-European hydrological datasets, JRC Flood Hazard Risk Maps 20y/50y/100y/200y/500y (100m), and Harmonized World Soil Database (HWSD). It is based on spatial modelling indicating the disposition of an area to host riparian features. The calculation is based on the stratification of different hydrological and geomorphological parameters. These parameters are derived from the input datasets and are weighted differently depending on their significance and quality. The resulting parameters are combined into a single layer expressing the likelihood (above 50 % of membership degree for a vector layer) of an area to be part of a Potential Riparian Zone. The temporal reference is 2010-2014 (Weissteiner et al. 2016).

The webpage description of the product metadata adds some details on the methodology of creation of the product. They are as follows: "the delineation of Riparian Zones is based on a complex spatial modelling approach, making use of the Riparian Zones' LC/LU classification, large-scale earth observation data and a range of additional geo-data sources, as well as derived spatially explicit indicators. Inputs are regionally parameterised and weighted according to relative importance in a fuzzy modelling approach. The zones provide a majority of riparian functions with a focus on ecosystem services. The production of the Riparian Zones products was coordinated by the European Environment Agency in the frame of the EU Copernicus programme" (Riparian Zones, 2022).

The illustration of the relative extent of the three Delineation product components is exemplified in Figure 2.

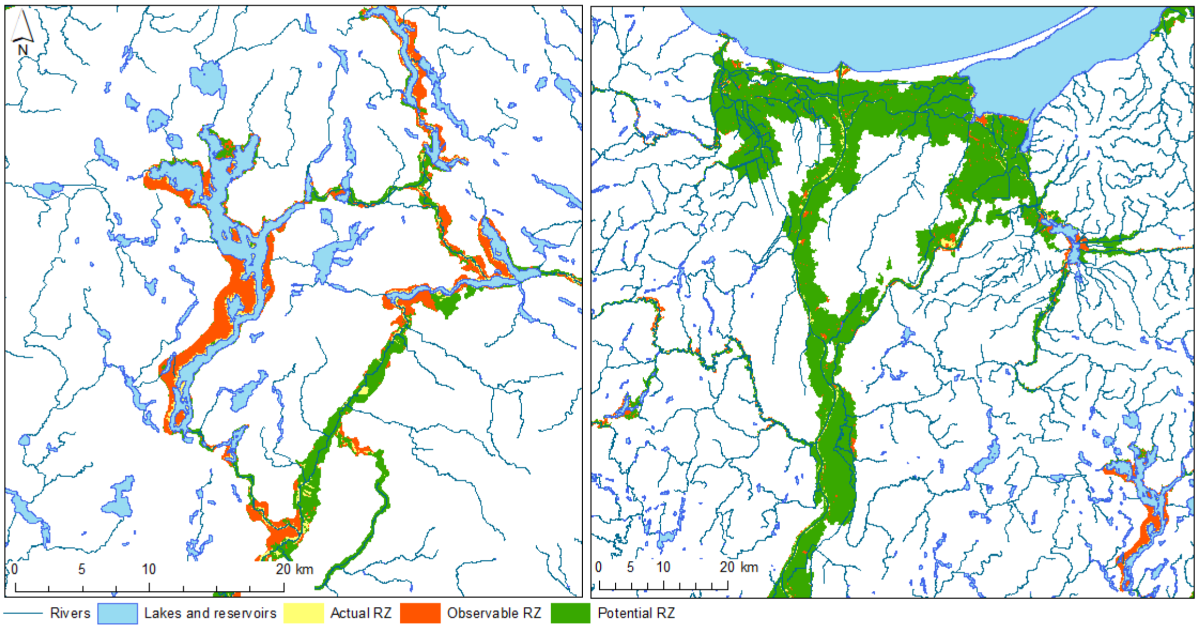


Figure 2. Delineation of Riparian Zones and their relative extent. The Actual RZ layer is completely within the Observable RZ layer, and these two are completely within the Potential RZ layer.

For all the three products, the details of modelling and decisions made in classification are not clear to the user. The accuracy check for the three products, according to the available documentation is "Qualitative Expert Assessment". This makes the need to verify the accuracy of the product even more necessary.

2.1.3 Comparison of Delineation of Riparian Zones layers with Riparian Zones LC/LU

The Riparian Zone Delineation layers and Riparian Zone LC/LU product are not compatible in terms of their extent. Comparison of the two products reveals that their extent is not identical (Figure 3). In general, the Delineation of Riparian Zones maximum extent is completely contained within the Riparian Zone LC/LU extent, but the latter extends beyond the potential delineation layers. The extended area includes mainly buffers along some small rivers not included in PRZ, along floodplains and estuaries of some large and middle size rivers, and around reservoirs (Figure 3). The product description available at the data provider does not explain why the two products differ in extent, or what was the procedure of selecting rivers and the extent of buffer zone in the RZ LC/LU product.

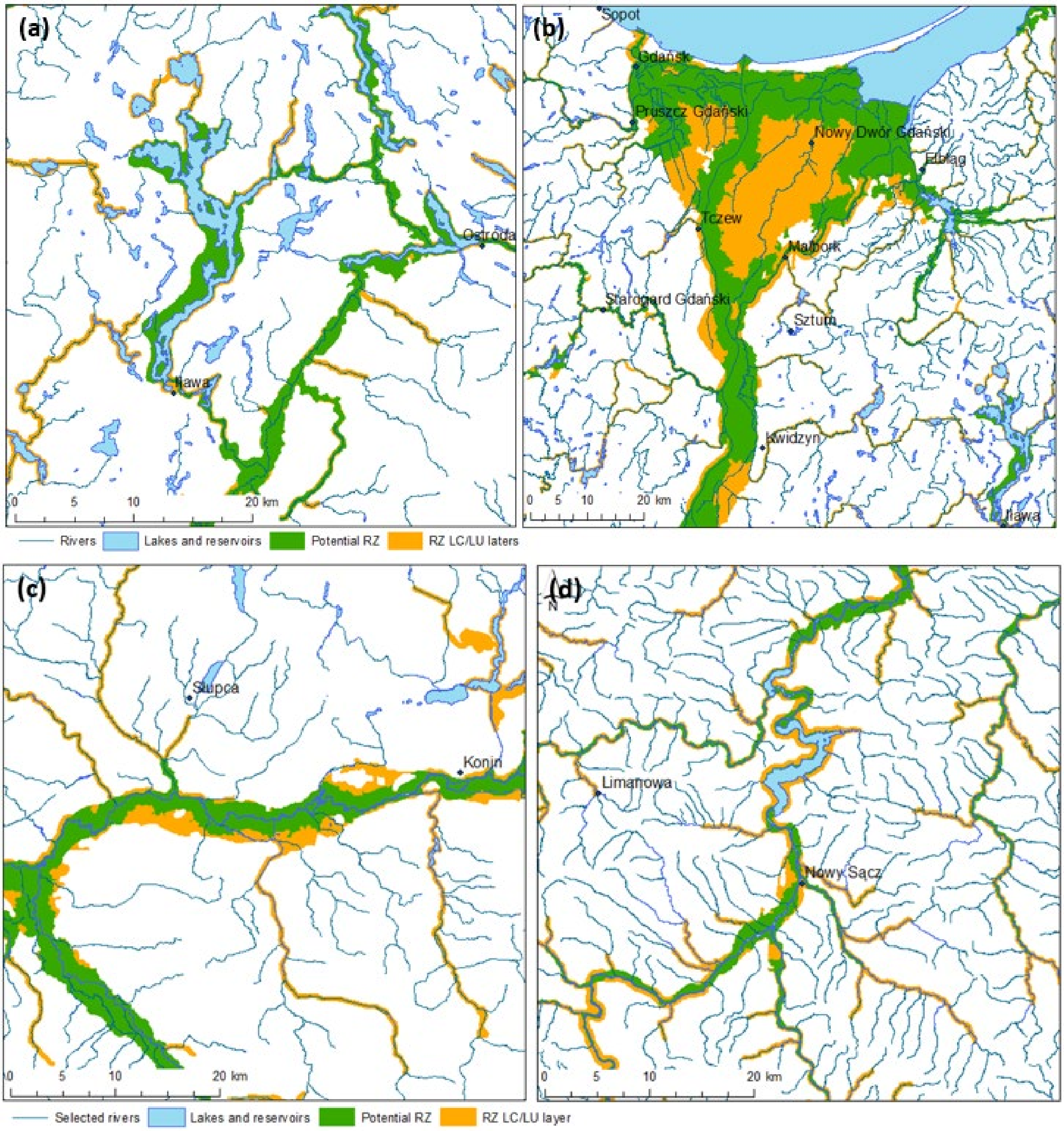


Figure 3. Some examples of Potential Delineation of Riparian Zones and Riparian Zone LC/LU products, for a) lakeland area, b) large river delta, c) middle size lowland rivers, d) sub-mountainous rivers.

2.2 HRL-SWF 2018

For the 2018 reference year the Copernicus Land Monitoring Service (CLMS) provides the primary product Small Woody Feature (SWF) in vector and raster (5 m spatial resolution) format and Woody Vegetation Mask (WVM). For experienced users with a deep understanding of derived data from satellite remote sensing, the EEA also publishes Expert Products e.g. Forest Mask (FM) and SWF Confidence Layer – both in 5 m spatial resolution. In this analysis the Small Woody Feature (SWF) and Forest Mask (FM) were examined.

The **Small Woody Feature (SWF)** product is a thematic product showing the occurrence of small structures of trees, hedges, bushes and scrub. In the SWF 2018 production, there were used different geometric rules than in SWF 2015. The main difference was the omission of the Additional Woody Features (AWF) in production of SWF 2018. Additionally, the discrimination between linear or patchy features is not visible in the final SWF 2018 product. The SWF 2018 raster product is derived from SWF 2018 vector product by using a conversion to the raster format compliant with the EEA grid.

The main source of data for the HRL SWF 2018 production is the European Space Agency (ESA) Copernicus Space Component Data Access (CSCDA) providing the VHR_IMAGE_2018 dataset with complete, cloud-free coverage (CLMS 2021). The SWF dataset is derived from Very High Resolution (VHR) satellite imagery from Copernicus Contributing Missions (CCMs). Each VHR was delivered in two processing levels: level 1 and level 3 (ortho-rectified) at 2-4 m spatial resolution for four spectral bands (blue, green, red and NIR). The VHR_IMAGE_2018 dataset was acquired from the selected satellite missions: Pleiades, PlanetScope, SuperView-1, Kompsat-3/3A, SPOT 6/7 and TripleSat.

Compared to the VHR_IMAGE_2015 used for HRL SWF 2015 production, the new VHR_IMAGE_2018 has the advantage of improved geometric correction, a cloud mask and gap filling. Unfortunately, the spatial resolution was reduced from 1 m to 2-4 m and the panchromatic band was no longer used, so that the pan-sharpening operation could not be performed.

Thematic definitions of SWF 2018 are provided in the Small Woody Features 2018 User Manual (CLMS 2021) and are presented in Table 3, including both the elements to be included and those to be excluded in the SWF layer.

Table 3: Thematic definition of SWF 2018 (source: CLMS 2021)

Elements included in small woody features	Elements excluded from small woody features
• linear hedgerows and scrubs • tree rows (along field boundaries) • isolated/scattered patches of trees areas, storm damages, insect-infested damages, etc.)	• stone walls • drainage ditches • grass margins • field boundaries without hedgerows or trees • any kind of "grey" infrastructure such as roads • artificial tree rows like olive tree plantations, vineyards, and orchards

The **Forest Mask 2018 (FM)** layer was produced on the basis of the HRL Tree Cover Density 2018 (TCD) layer taking into account the established technical specifications. The use of the TCD layer was intended to eliminate the overlap of the SWF product with large and densely tree covered areas, hence the use of the mask approach.

The SWF 2018 dataset is not available on the Copernicus website, because the product quality is still being assessed. A version of the SWF 2018 product (for Poland and Norway) was made available for our consortium in order to carry out analyses.

2.3 Reference datasets for Poland

2.3.1 Topographic object database at scale 1:10 000 (BDOT10K)

Topographic objects database at scale 1:10 000 (BDOT10K) provides data over the entire country with a level of detail corresponding to the topographic maps at 1:10 000. The BDOT10K is provided in a vector format (reference year 2015-2018). It is derived and updated partially using manual interpretation of aerial orthophotos. BDOT10K contains objects with three levels of detail. Level 1 consists of the following classes: water network, communication network, utility network, land cover, buildings and facilities, complexes of land use, administrative divisions and other objects. Some level 2 classes were also used, as listed in Table 5. We used the BDOT10K obtained in the year 2018.

2.3.2 LUCAS Land Use/Cover Area frame Survey

LUCAS provides harmonised and comparable statistics on land use and land cover. The data are gathered through direct observations made by surveyors on the ground. LUCAS is based on statistical calculations that interpret observations in the field. The collected data provide information for studying a range of socio-environmental issues, like land uptake, soil degradation or biodiversity. Land cover refers to the bio-physical coverage of land, such as natural areas, forests, buildings and roads or lakes. Whereas land use refers to socio-economic use of land, like agriculture, commerce, residential or recreational use.

Table 4. Summary of LUCAS data classes used in the comparison with Riparian Zones.

1st level of detail		2nd level of detail	
A00	Artificial Land	A10	Roofed built-up areas
		A20	Artificial non-built-up areas
		A30	Other artificial areas
B00	Cropland	B10	Cereals
		B20	Root crops
		B30	Non-permanent industrial crops
		B40	Dry pulses, vegetables and flowers
		B50	Fodder crops
		B70	Permanent crops: fruit trees
		B80	Other permanent crops
C00	Woodland	C10	Broadleaved woodland
		C20	Coniferous Woodland
		C30	Mixed woodland
D00	Shrubland	D10	Shrubland with sparse tree cover
		D20	Shrubland without tree cover
E00	Grassland	E10	Grassland with sparse tree/shrub cover
		E20	Grassland without tree/shrub cover
		E30	Spontaneously re-vegetated surfaces
F00	Bare land and lichens/moss	F10	Rocks and stones
		F20	Sand
		F30	Lichens and moss
		F40	Other bare soil
G00	Water areas	G10	Inland water bodies
		G20	Inland running water
		G30	Transitional water bodies
H00	Wetlands	H10	Inland wetlands
		H20	Coastal wetlands

LUCAS provides information in a vector format (points). At the 1st level of detail, there are eight classes: A00 – Artificial Land, B00 – Cropland, C00- Woodland, D00 – Shrubland, E00 – Grassland, F00 – Bare land and liches/moss, G00 – Water areas and H00 – Wetlands. LUCAS data have three levels of data detail, but for the comparison between Riparian Zones and LUCAS we used the first and second level of detail. Classes from the 2nd level of detail are presented in Table 4.

2.3.3 National flood maps

Flood risk maps were prepared in accordance with the requirements of Floods Directive *(DIRECTIVE 2007/60/EC*, 2007) and in close coordination with Water Framework Directive processes. In Poland, the National Protection Information System (ISOK) has been launched and the flood maps were made available to the public with web-based services from Hydroportal (https://isok.gov.pl). The methods used to create the flood zone maps are based on hydraulic modelling with the use of LiDAR DEM of 1 m spatial resolution and 20 cm vertical accuracy (PGW Wody Polskie, n.d.). The available maps include layers of different flood zone scenarios, e.g. 10-years, 100-years, 500-years flood, and a scenario of floodgates breakdown (Figure 4). For this study, we used the 100-years return flood zone and the floodgates breakdown scenario.

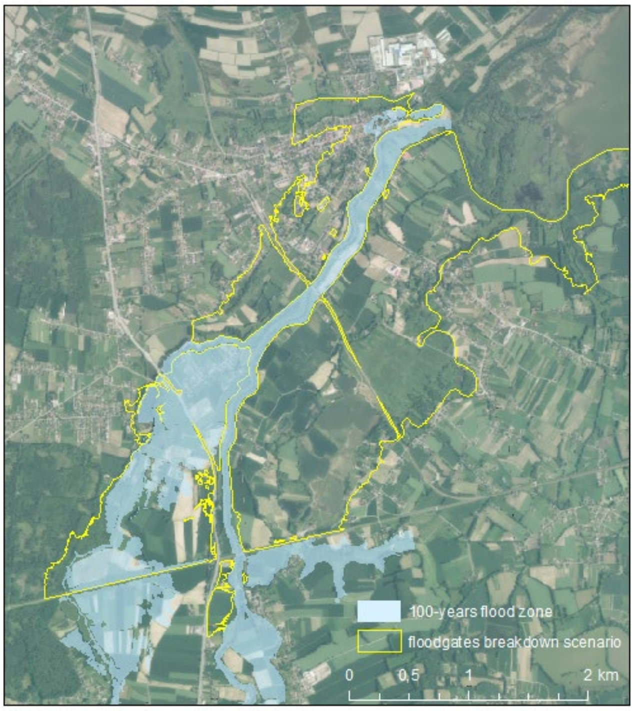


Figure 4. Illustration of the selected flood maps content: 100- years flood zone and the extent of floodgates breakdown scenario.

2.3.4 National orthophotos

Arial orthophotos were used for visual inspection. The aerial orthophotos are accessible via the Polish national geoportal (www.geoportal.gov.pl). The majority of the national orthophotos was acquired between the year 2010-2013 and 2017-2020. The national aerial orthophotos, both current and archival, are accessible in WMS and WFS services on the national geoportal available from Head Office of Geodesy and Cartography (GUGiK).

2.4 Reference datasets for Norway

2.4.1 The Area Frame Survey of Norway: AR18x18

The most detailed "ground truth" of land cover in Norway is the Area Frame Survey of land cover and outfield land resources, abbreviated as AR18x18 (Strand 2013). This comprises a systematic random sample of 1081 Primary Statistical Units (PSU) of 1500 × 600 m (0.9 km^2), located at 18 km intervals over the whole of Norway. The sampling design was the same as for the first generation of the LUCAS programme, carried out in the EU countries by the European Statistical Agency (Eurostat 2003).

In AR18x18, each PSU rectangle was fully mapped in the field using a national vegetation mapping system, with 54 classes (Rekdal & Bryn 2010). The full classification system, with definitions, is available in Bryn et al. 2018.

2.4.2 National flood maps

Information on flood risk in Norway are available from two data sources, a flood awareness map and a flood zone map, with different accuracy and areas of use (NVE 2022). The flood awareness map is a national covering dataset that on a "coarse" scale denote areas that might be exposed to flooding. These areas need further assessment in case of new development. Flood zone maps are only calculated for selected high risk river basins but using statistics and hydraulic modelling. Flood zones are calculated for different return periods. For this study, we use areas where a 100-year flood zone has been calculated. The flood zone maps are available from the web-based service Geonorge (www.geonorge.no).

2.4.3 National orthophotos

Wall-to-wall aerial orthophotos were used for visual inspection of the data. These are made freely available through *Norge digitalt*, a collaboration between different national and local authorities and organisations that provide or use spatial information. They are available as an application (www.norgeibilder.no) and as WMS service.

3 Methods

To examine the thematic accuracy in detail, we carried out spatial overlays between national datasets and Riparian Zones (RZ) 2018. The spatial overlays provided information on the area occupied by the same or similar classes. This allowed discrepancies between classes to be identified.

The data were summarised as 'confusion matrices', with the RZ classes as row headings and the national classes as column headings, where each cell shows the percentage of area for that particular combination of classes. We calculated:

- User accuracy: how often the RZ class is actually present in the national datasets, i.e. the percentage distribution of each RZ class amongst the national dataset classes (where 100% is the total area in the RZ class).
- Producer accuracy: how often data in the national dataset is correctly shown in RZ, i.e. the percentage distribution of each national class among the RZ classes (where 100% is the total area in the national class).

In addition to showing the degree of correspondence, these tables can be used to examine discrepancies and to see whether there are systematic trends or consistent misinterpretation between specific classes. In analysing the results, we were careful to consider whether differences could be due to differences in definitions between RZ and the national datasets. The spatial overlay of RZ and national datasets was done using vector formats, both for Poland and Norway. The analyses were carried out at the country scale.

Below we provide more methodological details related to the national datasets used.

3.1 Comparing Riparian Zones 2018 with national topographic data for Poland

The definitions of the classes in RZ 2018 were compared with the classes in BDOT10K. The classes from BDOT10K were then assigned to classes from RZ and clipped to their boundaries. Depending on the availability of data, we used level 2 of the classification system, in the absence of detailed data, we used level 1. Thus, for classes 4. Grassland and 5. Heathland and scrub, we used level 1, whilst the other classes were analysed at level 2.

The spatial distribution of BDOT10K data corresponding to those from RZ and clipped to RZ boundaries is presented in Figure 5.

A summary of BDOT10K data used for each class from RZ is presented in Table 5. Due to a discrepancy in the nomenclatures some of the classes like Grassland, Heathland and scrub and Wetland it was decided to prepare data on the first level of detail.

Another approach was undertaken towards Wetland class (Class 7), because in BDOT10K database this class by nature can be present over different land cover classes like forest, arable land or grassland. Furthermore, Class 6: Open spaces with little or no vegetation was dropped due to lack of relevant data. For the other classes, the most appropriate data were selected for the 2nd level of detail.

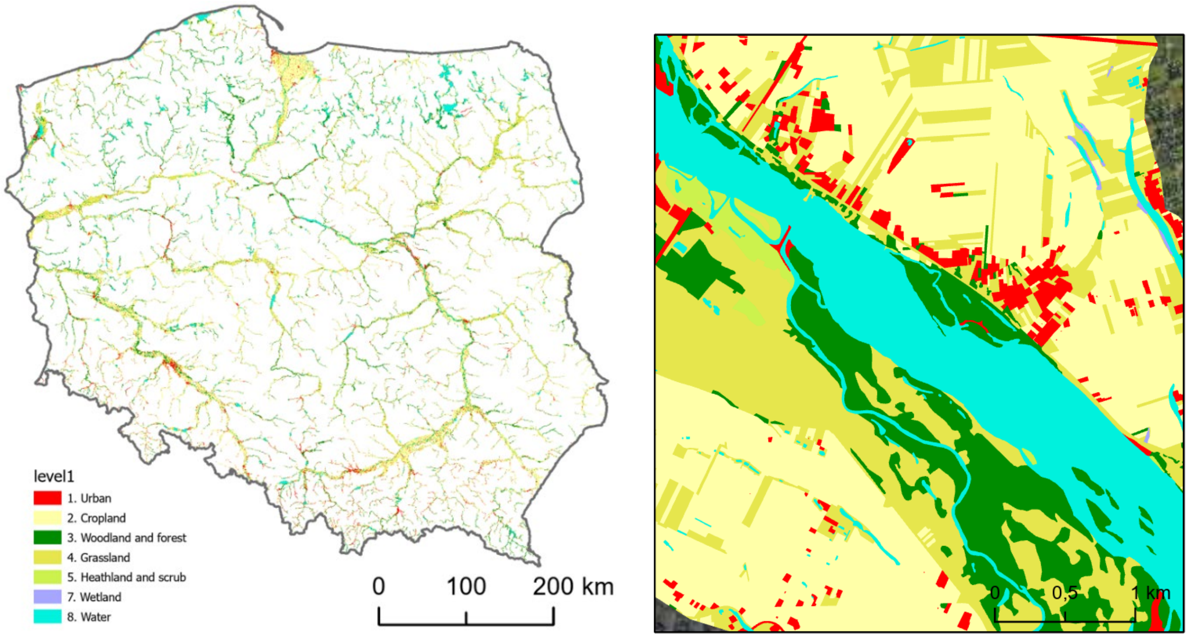


Figure 5: Overview of BDOT10K data corresponding to the Riparian Zones class for Poland.

Table 5. Summary of BDOT10K data classes used for each class from Riparian Zones.

Riparian Zones Level-1 class	Riparian Zones Level-2 class	National data source (BDOT10K) class name
1 Urban	1.1 Urban fabric, industrial, commercial, public, military and private units	**PTZB** – development, **KUPG** – industrial and economic complex without: KUPG06 – mine, KUPG11 – landfill, **BU** – building, structures and equipment without: BUBD 1271.SZ greenhouse or hothouse, BUIT05 – fuel dispenser complex, BUSP – sports building, BUIB – other building, BUTR – transport facility, **PTNZ** – other undeveloped land, **KUKO08** – petrol station, **KUHU** – shopping and service complex, **KUOS** – educational complex, **KUOZ** – health and social care complex, **KUSC** – sacra complex and cemetery, **KUZA04** – museum complex, **KUZA06** – castle complex, **KUIK** – other land use complex, **KUMN** – residential complex, **KUHO** – hotel services complex, **PTPL** – square
	1.2 Transport infrastructure	**PTKM** – land under roads, railways and airports, **KUKO** – communication complex without: KUKO08 – petrol station, **BUIT05** – fuel dispenser complex
	1.3 Mineral extraction, dump and construction sites, land without current use	**KUPG06** – mine, **KUPG11** – waste disposal site, **PTWZ** – pit and heap, **PTGN** – unused land
	1.4 Green urban, sports and leisure facilities	**KUSK** – sports and recreation complex, **BUSP** – sports building, **PTUT01** – allotment garden
2 Cropland	2.1 Arable land	**PTTR02** – arable land, **OIOR10** – greenhouse (other than buildings), **BUBD 1271.SZ** – greenhouse or hothouse, **PTUT05** – ornamental plant nursery
	2.2 Permanent crops	**PTUT03** – orchards, **PTUT02** – plantation
3 Woodland and forest	3.1 Broadleaved forest	**PTLZ** – forest and wooded area, type: deciduous
	3.2 Coniferous forest	**PTLZ** – forest and wooded area, type: coniferous
	3.3 Mixed forest	**PTLZ** – forest and wooded area, type: mixed
	3.4 Transitional woodland and shrub	**PTUT04 –** forest nursery
4 Grassland		**PTTR01** – grassy vegetation (cut with KUSK - sports and recreation complex)
5 Heathland and scrub		**PTRK02** – shrubs, **PTRK01** – mountain pine
7 Wetland		**OIMK** – wetland, **OISZ –** rushes
8 Water	8.1 Water courses	**PTWP02** – running water
	8.2 Lakes and reservoirs	**PTWP03** – still water

3.2 Comparing RZ 2018 with LUCAS data for Poland

For the comparison between RZ 2018 and LUCAS, we used LUCAS data from the first and second level of detail. The LUCAS points clipped to RZ boundaries for Poland is presented in Figure 6.

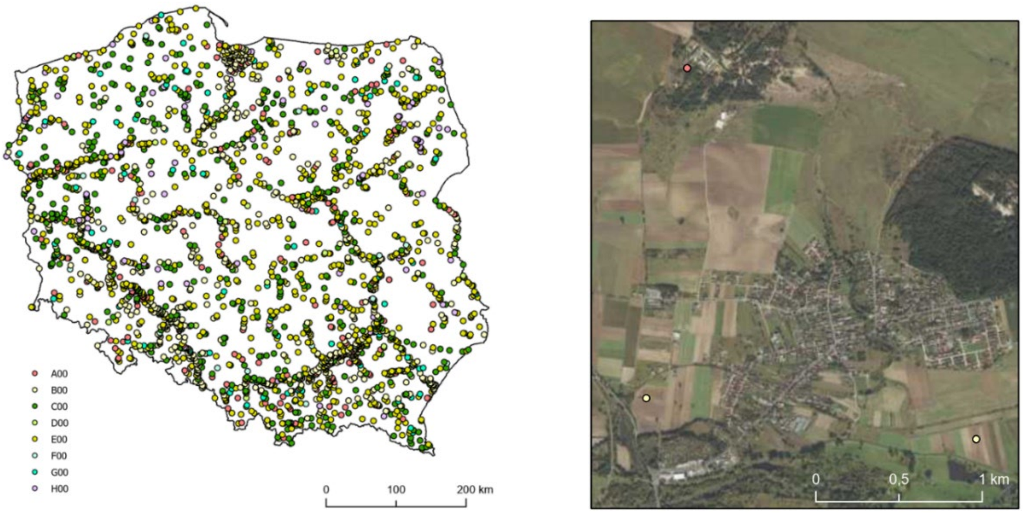


Figure 6: Visualisation of LUCAS data (A00 – Artificial Land, B00 – Cropland, C00 – Woodland, D00 – Shrubland, E00 – Grassland, F00 – Bare land and lichens/moss, G00 – Water areas, H00 - Wetlands) clipped to Riparian Zones boundaries in Poland.

3.3 Comparing RZ 2018 with Small Woody Features 2018 (SWF) layer for Poland

Small Woody Features (SWF) and Forest Mask (FM) were used for analyses. The original data from the listed products were combined for Poland and then clipped to the boundaries of the Riparian Zones. Class SWF area from SWF layer and class forested area from FM layer were combined into one class. The spatial distribution of the merged SWF and FM layers was clipped to Riparian Zones boundaries over Poland and is presented in Figure 7.

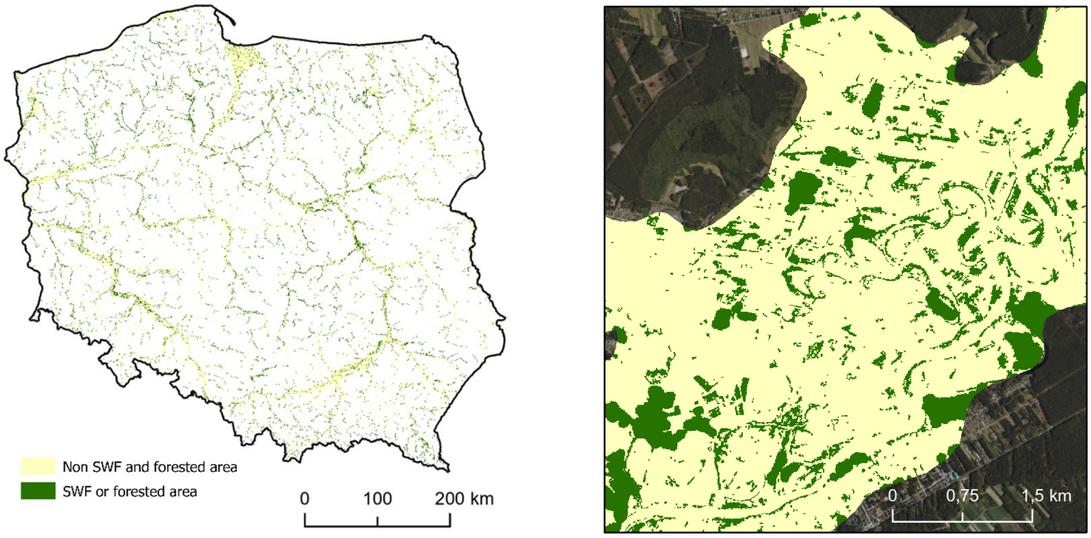


Figure 7: Visualisation of merged Small Woody Features and Forest Mask data clipped to Riparian Zones boundaries in Poland.

3.4 Comparing RZ 2012-2018 change layer with national orthophotos for Poland

To verify the RZ LC/LU 2012-2018 change layer, we used aerial orthophotos from 2010-2013 and 2017-2020. The time range was chosen to be consistent with the reference data for execution of the RZ LC/LU 2012-2018 change layer. Figure 8 shows the availability of national orthophotos.

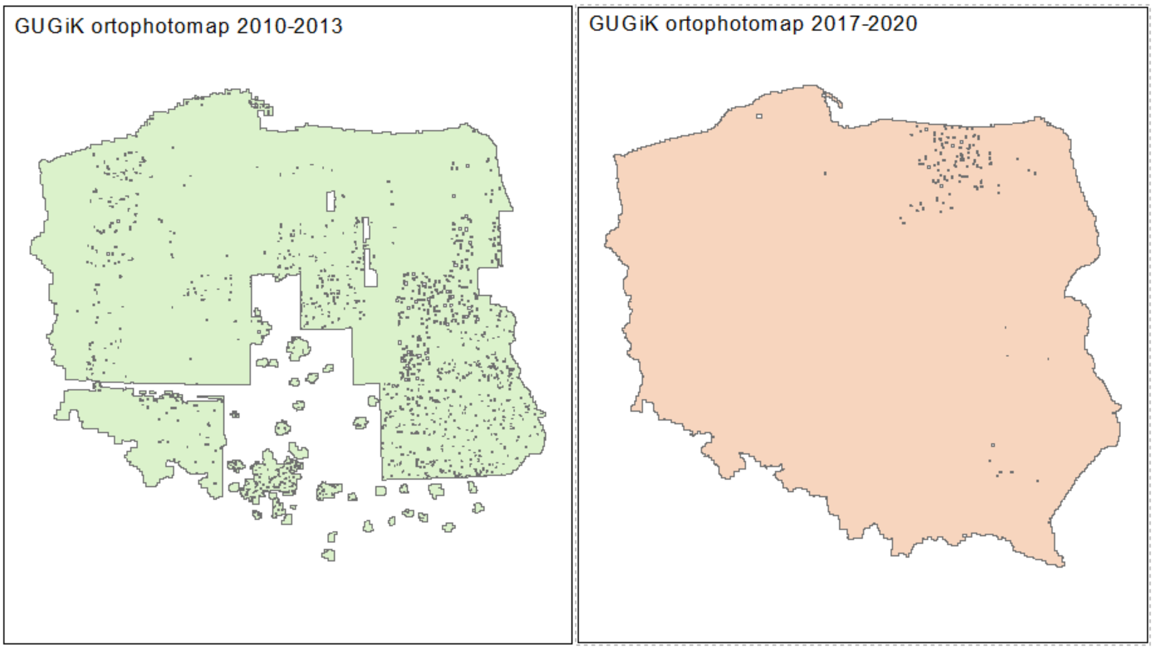


Figure 8: Availability of national orthophotos: at least one image coverage in the appropriate time scope.

The initial accuracy check for the RZ 2012-2018 change product used a random sampling method. For each class, random points were distributed, then the polygons in which the points fell were visually inspected against the relevant orthophotos. For each polygon we aimed to assess whether the classification was accurate both in 2012 and 2018.

At the beginning of the exercise, we realised that the reference time scope of the RZ LC/LU products of four years makes the accuracy check procedure ineffective and unreliable. Four years is quite a long period for such a dynamically changing landscape as riparian zones. Not knowing what time a particular LULC class delineation was made makes the matching of relevant orthophotos very uncertain. Therefore, we chose instead to present selected case examples to illustrate various aspects that we encountered in the verification of this dataset.

3.5 Comparing RZ extent with national flood maps for Poland

To compare RZ_2018 with the Polish flood zone map, we used the 100-years flood map which shows an extent of the modelled flooded area at height of 100 years recurrency. The extent of this area excludes those areas of floodplain that are disconnected from the river through dikes. However, dikes are man-made structures that limit the floodplain available to the river water, and thus do not show the real extent of a potential floodplain. To take account of this, we also used a combination of the 100-years flood layer with the extent of flooding modelled for floodgates breakdown scenario. This layer shows a more probable extent of the real floodplain.

3.6 Comparing RZ 2018 with the Area Frame Survey (AR18x18) for Norway

Since AR18x18 is based on field survey, whilst RZ 2018 uses satellite data, there are differences in definitions between the classification systems. Nevertheless, the legend of AR18x18 can be nested quite logically within the RZ level 1 categories (Table 6). For Woodland and forest, we might expect correspondence with the RZ level 2 categories, 3.1 Broadleaved forest and 3.2 Coniferous forest. On the other hand, there is no category in AR18x18 corresponding to 3.3 Mixed forest, since it is easier in the field to decide on a dominating type (and few forests in Norway are an even mix of broadleaves and coniferous). The class 3.4 Transitional woodland and scrub is also missing from the AR18x18 legend, since the forest type can still be identified in the field, from the species present, and the transitional nature is considered a "condition", rather than a vegetation type.

Both RZ 2018 and AR18x18 mix the concepts of land use and land cover by having a separate category for agricultural land. In AR18x18, the level 1 class Farmland is split into Cultivated land and Pastures. In RZ 2018, the level 1 class Cropland should capture most farmland, including fodder crops, whilst Managed grassland comes under level 1 class Grassland.

Table 6. Expected correspondence between the classes of RZ 2018 and the classes of AR18x18.

RZ classes, level 1	RZ classes, level 2	AR18x18 land cover groups
1. Urban		Built-up areas
2. Cropland		Farmland (11a Cultivated land)
3. Woodland and forest	3.1 Broadleaved forest	Boreal deciduous forest
		Broad-leafed deciduous forest
	3.2 Coniferous forest	Pine forest
		Spruce forest
		Peatland forest
4. Grassland		Farmland (11b Pastures)
		Alpine meadow communities
5. Heathland and scrub		Alpine heath communities
		Non-forested dry land below the treeline
6. Open spaces with little or no vegetation		Snow-bed vegetation
		Non-productive areas
7. Wetland		Wetlands
8. Water		Freshwater

3.7 Comparing RZ 2012-2018 change layer with national orthophotos for Norway

For Norway, we aimed to use the same method as for Poland. We identified areas with aerial photos from both 2012 and 2018 and distributed random points over the map. Unfortunately, the number of examples of each type of change was too low to provide a meaningful verification. It then became clear from the work in Poland that our intended method would not work anyway, since the reference years 2012 and 2018 each include images from several years, and the data do not provide information about the years used for any given scene or polygon.

3.8 Comparing RZ extent with national flood maps for Norway

As described in Weissteiner et al. (2016, p. 4), a flood hazard map delineating the 100-year flood zone was combined with the Riparian Zone initial river buffer widths as one of several steps to create the Riparian Zone area of interest. In Norway, 100-year flood zones have been calculated for 73 river segments (Figure 9). We overlaid the different 100-year flood segments with the Riparian Zone extent to check for similarities and differences.

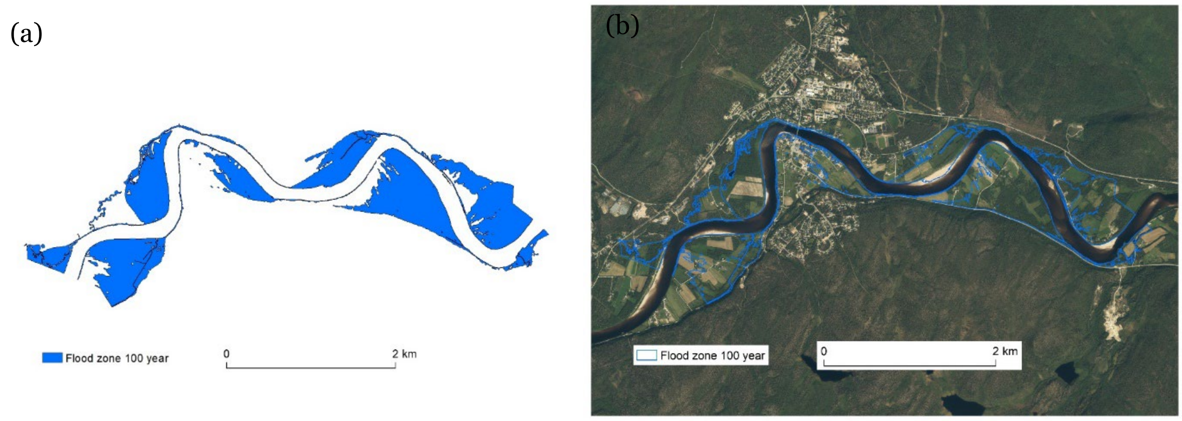


Figure 9: a) Flood zone 100-year calculation for a river segment in Norway, b) Flood zone 100-year calculation for a river segment in Norway with orthophoto background.

4 Results

4.1 Comparing RZ 2018 with national topographic data for Poland

Table 7 presents the **user accuracy**, i.e. the percentage distribution of each RZ class amongst the BDOT10K classes. Overall, at level 1, the user accuracy for the Urban class was about 62 %. In total, 65 % of the area of class 1.1: 'Urban fabric, industrial, commercial, public, military and private units' in RZ overlapped with class 1.1 in BDOT10K. The remaining 20 % was classified as Grassland, and more than 8.6 % as Cropland in BDOT10K.

Almost 62 % of the area of Class 1.2: 'Transport infrastructure' overlapped with the equivalent class in BDOT10K, whereas 16 % and 14 % were assigned as class 1.1 and class 4 (Grassland), respectively. More than 33 % of area occupied by class 1.3: 'Mineral extraction, dump and construction sites or land without current use', was assigned to Grassland, and 13 % to Urban fabric. Of interest, 50 % of class 1.4: 'Green urban, sports and leisure facilities', corresponded to the equivalent class in BDOT10K.

More than 83 % of the area of Arable land overlapped with the corresponding class in BDOT10K. The remaining area was assigned to Grassland (14 %). 67 % of the class Permanent crops overlapped with the equivalent class in BDOT10K, whilst more than 19 % was classed as Arable land.

There was quite good user accuracy for Coniferous Forest (63 %), whereas Broadleaved Forest and Mixed Forest showed much lower correspondence with BDOT10K, 40 % and 33 %, respectively. More than 16% of the Broadleaved Forest in RZ was in the Grassland class in BDOT10K. The transitional woodland and scrub class overlapped 28 % with Grassland in BDOT10K. More than 42 % of the area occupied by class 3.5: 'Lines of trees and scrub' was on Arable land and 34 % in Grassland in BDOT10K.

Of the area classified as Managed grassland in RZ, 70 % was grassland in BDOT10K, and of the area classified as Natural grassland, 77 % was grassland in BDOT10K. Almost 23 % of Managed grasslands in RZ were classified as Croplands in BDOT10K.

The **producer accuracy** (Table 8) shows how often the BDOT10K classes, translated to Riparian Zones classes, are correctly shown in Riparian Zones. Among the Urban classes, the highest agreement between RZ and BDOT10K was obtained for the class 1.1: Urban fabric, industrial, commercial, public, military and private units (76 %), followed by Green urban (60 %), Transport infrastructure (50 %), and Mineral extraction (34 %). Transport infrastructure class in BDOT10K felled on Urban fabric (18 %), Grasslands (10 %) and Arable land (7 %) in RZ. Mineral extraction class in BDOT10K overlapped in 22% with the class: Lakes and reservoirs in RZ.

Among the Cropland classes, the class Arable land showed the highest agreement up to 73 % with BDOT10K, and around 20 % of this class was classified as Grasslands in RZ. Much lower agreement was observed in Permanent crop class (40 %), and remaining areas were assigned into Arable land (13 %), Heterogenous agricultural areas (13 %), and Grassland classes (14 %) in RZ.

There is a good agreement among the Grassland classes in RZ and BDOT10K. Around 70% of Grassland in BDOT10K were assigned to Managed and Natural & Semi-natural grasslands in RZ. Almost 12% of them felled into Arable land class in RZ.

In general, there was disagreement among woodland and forest classes between RZ and BDOT10K. Broadleaved forest in BDOT10K is misclassified as Coniferous forest and Mixed Forest in RZ and vice versa. The lowest agreement was observed in Mixed forest (17 %), where 35 % of it in BDOT10K was assigned to Coniferous and 32 % to Broadleaf forest in RZ. There was no agreement between Heathlands and shrub class in the datasets.

Table 7. User accuracy: the percentage distribution of each Riparian Zones class amongst the BDOT10K classes assigned to the Riparian Zones 2018 classes, where 100 % is the total area in each Riparian Zones class (rows sums). Coloured cells show the expected correct correspondence between classes, Poland; note: *refers to classes with no name in the RZ (see Figure 1).

		BDOT10K	Urban				Cropland		Woodland and forest				Grassland	Heathland and scrub	Water		Total
			1.1	1.2	1.3	1.4	2.1	2.2	3.1	3.2	3.3	3.4	4	5	8.1	8.2	
RIPARIAN ZONES	1.1	Urban fabric, industrial, commercial, public, military and private units	65.0	2.0	0.1	0.9	7.4	1.2	1.3	0.6	0.6	0.0	20.3	0.1	0.2	0.3	100.0
	1.2	Transport infrastructure	16.0	61.8	0.1	0.6	3.6	0.2	1.5	0.9	0.8	0.0	13.5	0.1	0.7	0.3	100.0
	1.3	Mineral extraction, dump and construction sites, land without current use	13.5	2.6	26.1	0.4	16.2	0.4	2.3	1.1	1.3	0.0	33.2	0.7	0.4	1.8	100.0
	1.4	Green urban, sports and leisure facilities	15.8	2.3	0.2	50.2	1.3	0.5	6.4	0.6	1.9	0.0	19.3	0.2	0.6	0.8	100.0
	2.1	Arable land	0.9	0.2	0.0	0.1	83.1	0.5	0.5	0.3	0.2	0.0	13.9	0.1	0.1	0.1	100.0
	2.2	Permanent crops	2.4	0.1	0.0	0.0	19.3	67.0	1.5	1.1	0.6	0.0	7.7	0.1	0.0	0.3	100.0
	2.3	Heterogeneous agricultural area	2.5	0.4	0.0	0.4	57.0	12.1	1.2	0.5	0.4	0.0	25.2	0.1	0.1	0.2	100.0
	3.0*		4.6	0.6	0.2	2.2	0.8	0.3	43.0	17.4	16.3	0.0	11.1	0.9	1.0	1.4	100.0
	3.1	Broadleaved forest	1.9	0.3	0.1	0.7	3.4	0.5	40.4	12.8	19.1	0.0	16.2	1.9	1.2	1.6	100.0
	3.2	Coniferous forest	1.4	0.2	0.0	0.3	0.8	0.1	8.3	62.8	21.9	0.0	3.6	0.1	0.2	0.4	100.0
	3.3	Mixed forest	1.3	0.2	0.1	0.5	1.3	0.1	26.1	25.7	33.1	0.0	9.0	0.8	0.9	0.9	100.0
	3.4	Transitional woodland and scrub	1.3	0.2	0.9	0.1	4.2	1.2	16.0	26.5	13.3	0.0	27.7	6.3	1.2	0.9	100.0
	3.5	Lines of trees and scrub	1.2	2.1	0.1	0.2	42.5	0.7	9.4	0.8	2.5	0.0	34.4	1.3	3.5	1.3	100.0
	4.0*		4.7	0.7	0.2	0.7	17.4	1.1	3.7	0.4	0.8	0.0	67.9	0.8	0.8	0.8	100.0
	4.1	Managed grassland	1.4	0.3	0.1	0.1	23.0	0.5	1.6	0.7	0.7	0.0	70.4	0.3	0.3	0.6	100.0
	4.2	Natural & semi-natural grassland	1.2	0.3	0.4	0.1	7.9	0.2	4.5	1.9	1.6	0.0	77.4	1.5	1.0	1.9	100.0
	5.0*		7.4	1.5	12.2	1.2	2.5	1.5	8.6	0.5	5.3	0.0	53.4	3.6	1.5	0.9	100.0
	5.1	Heathland and moorland	0.0	0.3	0.1	0.0	6.8	0.0	17.7	12.6	15.8	0.0	35.1	10.4	1.1	0.1	100.0
	8.0*		1.8	1.3	0.3	0.4	0.0	0.0	0.4	0.0	0.1	0.0	1.9	0.1	34.0	59.6	100.0
	8.1	Water courses	0.3	0.6	0.4	0.0	0.8	0.0	1.8	0.5	0.7	0.0	6.8	0.3	67.0	20.7	100.0
	8.2	Lakes and reservoirs	1.5	0.0	1.1	0.1	0.4	0.0	0.3	0.2	0.1	0.0	1.8	0.1	1.2	93.2	100.0
	8.3	Transitional waters	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	1.3	0.5	0.0	97.8	100.0

Table 8. Producer accuracy: how often the BDOT10K classes assigned to the Riparian Zones classes were correctly shown in Riparian Zones 2018, where 100 % is the total area in each BDOT10K class (column sums). Coloured cells show the expected correct correspondence between classes, Poland; note: *refers to classes with no name in the RZ (see Figure 1).

		BDOT10K													
		Urban				Cropland		Woodland and forest				Grassland	Heathland and scrub	Water	
RIPARIAN ZONES		1.1	1.2	1.3	1.4	2.1	2.2	3.1	3.2	3.3	3.4	4	5	8.1	8.2
1.1	Urban fabric, industrial, commercial, public, military etc.	76.4	18.2	3.7	11.2	1.8	9.8	1.5	0.5	0.9	5.8	4.8	1.0	0.6	0.3
1.2	Transport infrastructure	1.7	49.6	0.3	0.6	0.1	0.1	0.2	0.1	0.1	0.1	0.3	0.1	0.2	0.0
1.3	Mineral extraction, dump and construction sites,unused land	0.8	1.2	33.8	0.2	0.2	0.1	0.1	0.1	0.1	0.0	0.4	0.5	0.1	0.1
1.4	Green urban, sports and leisure facilities	1.9	2.1	0.4	59.6	0.0	0.4	0.7	0.1	0.3	0.1	0.5	0.2	0.2	0.1
2.1	Arable land	3.9	7.5	3.1	2.2	73.3	13.4	2.0	0.9	1.1	29.8	11.8	2.9	0.9	0.5
2.2	Permanent crops	0.2	0.1	0.0	0.0	0.4	39.9	0.1	0.1	0.1	4.3	0.1	0.1	0.0	0.0
2.3	Heterogeneous agricultural area	0.4	0.5	0.1	0.7	1.8	12.7	0.2	0.1	0.1	4.8	0.8	0.2	0.0	0.0
3.0*		0.4	0.3	0.4	1.7	0.0	0.1	3.3	1.1	1.6	0.1	0.2	0.7	0.2	0.1
3.1	Broadleaved forest	2.5	3.1	3.8	9.0	0.9	4.1	53.0	13.4	31.7	10.2	4.4	28.2	4.3	1.8
3.2	Coniferous forest	1.7	1.7	1.0	3.4	0.2	0.6	10.4	63.5	35.2	6.8	0.9	1.6	0.8	0.4
3.3	Mixed forest	0.5	0.6	0.7	1.8	0.1	0.4	10.4	8.2	16.6	1.4	0.7	3.3	0.9	0.3
3.4	Transitional woodland and scrub	0.5	0.6	7.4	0.3	0.3	3.1	6.0	7.9	6.3	20.0	2.1	26.2	1.2	0.3
3.5	Lines of trees and scrub	0.0	0.1	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.1	0.0
4.0*		0.7	0.8	0.8	1.0	0.5	1.1	0.5	0.0	0.1	0.6	2.0	1.3	0.3	0.1
4.1	Managed grassland	5.5	8.1	7.5	5.7	18.3	12.9	5.8	2.2	3.1	15.2	54.0	13.3	3.4	1.8
4.2	Natural & semi-natural grassland	1.2	2.3	9.7	1.3	1.7	1.2	4.5	1.6	2.1	0.9	16.1	17.5	2.9	1.6
5.0*		0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0
5.1	Heathland and moorland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
8.0*		0.1	0.8	0.5	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	7.1	4.0
8.1	Water courses	0.1	2.0	3.4	0.1	0.1	0.0	0.7	0.2	0.4	0.0	0.6	1.3	73.6	7.3
8.2	Lakes and reservoirs	1.4	0.4	22.3	0.7	0.1	0.0	0.3	0.1	0.2	0.0	0.3	0.8	3.1	76.1
8.3	Transitional waters	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	5.2
Total		100	100	100	100	100	100	100	100	100	100	100	100	100	100

4.2 Comparing RZ 2018 with LUCAS data for Poland

In total, 2568 points from the LUCAS dataset was located within the extent of the Riparian Zones (RZ) (Table 9), with the most common classes being Grassland (36.6 %), Cropland (25.1 %), and Woodland (20.6 %). Comparison of the LUCAS points vs. RZ at the 2nd level of details is presented in Table 10.

About 76 % of the Artificial Land fell on the Urban class in RZ (139 points) and about 10 % fell on Cropland. One point was "mis-classified" due to an obvious difference in definitions, whereby greenhouses in LUCAS are assigned to the Artificial Land (A00) class, whereas the RZ definitions place them in the Cropland class. About 88 % of the Cropland points fell on Cropland in RZ and about 9 % fell on Grassland. For Woodland, about 75 % of points fell on Woodland and forest in RZ and about 12 % fell on Grassland. About 61 % of Shrubland fell on Grassland in RZ and about 18 % fell on RZ Woodland and forest. In the case of Grassland, about 61 % of points overlap with RZ Grassland and about 18 % of points overlap with RZ Cropland. About 46 % of Bare land and lichens/moss fell on RZ Urban and about 39 % fell on RZ Cropland, although it should be noted that there were only 28 points in total of this type. In the case of Water, about 83 % of points overlapped with Water in RZ. About 56 % of Wetlands fell on RZ Grassland and about 32 % fell on RZ Wetland.

Table 9. Comparison of LUCAS points with the Riparian Zones classes over Poland (1st level of detail). Coloured cells show the expected correct correspondence between classes.

Riparian Zones 2018 (RZ 2018)	LUCAS Artificial Land (A00)	Cropland (B00)	Woodland (C00)	Shrubland (D00)	Grassland (E00)	Bare land and lichens/ moss (F00)	Water areas (G00)	Wetlands (H00)	Total
Urban	139	15	41	3	108	13	2	0	321
Cropland	18	565	21	5	168	11	1	2	791
Woodland and forest	7	7	394	9	43	0	2	6	468
Grassland	17	58	63	30	573	3	8	58	810
Heathland and scrub	0	0	0	0	1	0	0	0	1
Open spaces with little or no vegetation	0	0	1	0	2	0	0	0	3
Wetland	1	0	6	2	37	0	3	33	82
Water	2	0	2	0	7	1	76	4	92
Total	184	645	528	49	939	28	92	103	2568

Table 10. Comparison of LUCAS points with the Riparian Zones 2018 classes over Poland (2nd level of detail).

	LUCAS																								
Riparian Zones	A10	A20	A30	B10	B20	B30	B40	B50	B70	B80	C10	C20	C30	D10	D20	E10	E20	E30	F10	F20	F40	G10	G20	H10	Total
1.1	69	51	0	2	0	1	2	0	7	0	25	3	7	1	2	19	58	14	1	0	4	0	1	0	267
1.2	0	5	0	0	0	0	0	0	0	0	2	0	0	0	0	0	2	0	0	0	0	0	0	0	9
1.3	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	1	0	6	2	0	0	0	17
1.4	2	7	0	0	0	0	0	0	3	0	3	1	0	0	0	4	7	0	0	0	0	0	1	0	28
2.1	2	12	1	410	22	59	13	23	6	2	14	3	3	2	1	9	106	29	0	0	11	1	0	2	731
2.2	0	1	0	2	0	0	0	0	12	0	1	0	0	1	0	0	1	0	0	0	0	0	0	0	18
2.3	1	1	0	13	0	0	0	0	3	0	0	0	0	1	0	5	13	5	0	0	0	0	0	0	42
3.0	0	0	0	0	0	0	0	0	0	0	3	3	0	0	0	0	0	0	0	0	0	0	0	0	6
3.1	0	3	0	3	0	0	1	0	0	0	112	9	24	2	2	5	10	6	0	0	0	0	2	1	180
3.2	1	2	0	0	0	0	0	0	0	0	16	97	46	1	0	2	2	1	0	0	0	0	0	1	169
3.3	0	0	0	0	0	0	0	0	0	0	25	8	12	0	0	1	2	2	0	0	0	0	0	1	51
3.4	1	0	0	0	0	0	0	0	1	1	26	5	7	3	1	2	3	7	0	0	0	0	0	3	60
3.5	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2
4.0	0	3	0	1	0	0	0	0	0	0	4	0	0	1	0	4	10	3	0	0	0	0	0	1	27
4.1	1	8	1	36	2	4	1	3	3	0	28	6	4	12	10	29	348	53	0	0	2	3	2	30	586
4.2	0	3	1	5	0	0	1	0	1	1	19	1	1	6	1	21	73	32	1	0	0	2	1	27	197
5.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
5.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
6.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	2
6.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.1	0	1	0	0	0	0	0	0	0	0	6	0	0	0	2	4	26	5	0	0	0	2	0	30	76
7.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1	0	3	6
8.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	2
8.1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	6	30	0	40
8.2	0	1	0	0	0	0	0	0	0	0	2	0	0	0	0	0	1	2	0	0	1	38	1	4	50
8.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	77	103	4	473	24	64	18	26	36	4	287	136	105	30	19	106	668	165	2	6	20	54	38	103	2568

4.3 Comparing RZ 2018 with SWF and FM data for Poland

The results of the comparison of Small Woody Features (SWF) and Forest Mask (FM) with Riparian Zones are shown in Table 11, in the form of User accuracy: the percentage distribution of each RZ class amongst the merged SWF and FM classes.

SWF or forest mask (FM) occurs in 39 % of the area of Heathland and shrub class, 14 % in Urban, 14.4 % in Wetlands and 14.2 % in Grasslands classes. Of interest, almost 11 % of the Woodland and forest areas in RZ were not present in SWF product.

The detailed analysis of the forest types in the context of SWF/FM showed that the Transitional woodland and shrub and Lines of trees and scrub are not always detected by the SWF and FM (Figure 10).

Table 11. User accuracy: the percentage distribution of each Riparian Zones 2018 class (1st level of detail) amongst the merged Small Woody Features (SWF) and Forest Mask (FM) classes, where 100 % is the total area in each Riparian Zone class (rows sums) ; note: *refers to classes with no name in the RZ (see Figure 1).

Riparian Zones (RZ)		Non-SWF and non-FM	SWF or FM	Total
1	Urban	85.7	14.3	100.0
2	Cropland	95.0	5.0	100.0
3	Woodland and forest	10.6	89.4	100.0
3.0*		10.1	89.9	100.0
3.1	Broadleaved forest	11.9	88.1	100.0
3.2	Coniferous forest	3.3	96.7	100.0
3.3	Mixed forest	6.1	93.9	100.0
3.4	Transitional woodland and shrub	35.0	65.0	100.0
3.5	Lines of trees and scrub	35.3	64.7	100.0
4	Grassland	85.8	14.2	100.0
5	Heathland and scrub	61.1	38.9	100.0
6	Open spaces with little or no vegetation	91.7	8.3	100.0
7	Wetland	85.6	14.4	100.0
8	Water	95.0	5.0	100.0

Figure 10 shows lines of trees indicated by Riparian Zones class: 3.5 lines of trees and shrubs, and Small Woody Features. These examples explain why about 35% of Riparian Zones are not demonstrated in SWF dataset.

Figure 10: Lines of trees: (a, b) Riparian Zones class: 3.5 Lines of trees and shrubs, and Small Woody Feature.

The producer accuracy (Table 12) shows how often the merged SWF and FM classes were correctly shown in Riparian Zones. The majority of SWF or FM (71 %) overlapped with Woodland and forest in RZ. Of the remaining area, 16 % of woody features were assigned to Grassland, 5 % to Cropland, 5 % to Urban and 1.7 % to Wetland and Water classes.

Table 12. Producer accuracy: how often the merged Small Woody Features (SWF) and Forest Mask (FM) classes are correctly shown in Riparian Zones (1st level of detail), where 100 % is the total area in each merged SWF and FM class (column sums).

Riparian Zones		Non-SWF and non-FM	SWF or FM
1	Urban	10.3	4.7
2	Cropland	35.2	5.1
3	Woodland and forest	3.1	70.6
4	Grassland	35.6	16.1
5	Heathland and scrub	0.0	0.0
6	Open spaces with little or no vegetation	0.2	0.0
7	Wetland	3.6	1.7
8	Water	12.0	1.7
	Total	100.0	100.0

To understand the discrepancy between comparable classes in RZ and merged SWF and FM classes, visual inspection was performed using the national aerial orthophotos. Examples of the comparison of RZ classes (1st level of detail) with SWF&FM classes are shown in Figure 11, Figure 12, Figure 13 and Figure 14.

Figure 11 and Figure 12 show examples of lines of trees, where the individual lines of trees were delineated in RZ, whereas the groups of trees were precisely identified in SWF and FM 2018 products.

Figure 11: Lines of trees: (a) aerial orthophoto, (b) Riparian Zones classes – 1st level of detail and (c) merged Small Woody Features and Forest Mask classes.

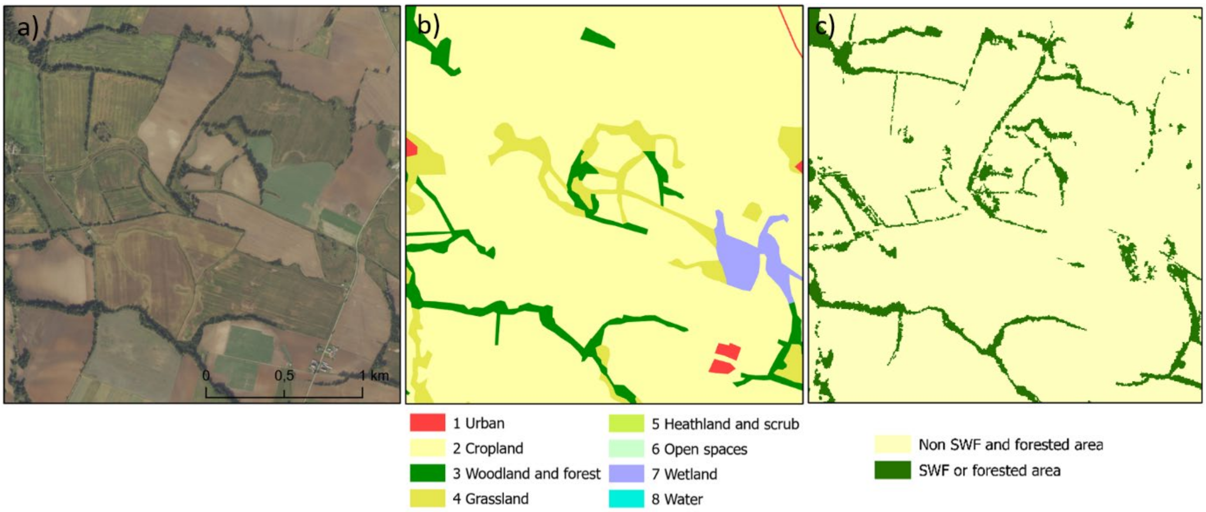


Figure 12: Lines of trees: (a) aerial orthophoto, (b) Riparian Zones classes – 1st level of detail and (c) merged Small Woody Features and Forest Mask classes.

Figure 13 shows an example of urban area, where the whole area is generalised and described as urban class in RZ, whereas the group of trees were precisely identified in SWF and FM products.

Figure 14 shows an example of a small river. In case of Riparian Zones, the entire extent of the river was assigned to the water class, whereas in SWF, the river area was misclassified as woodland.

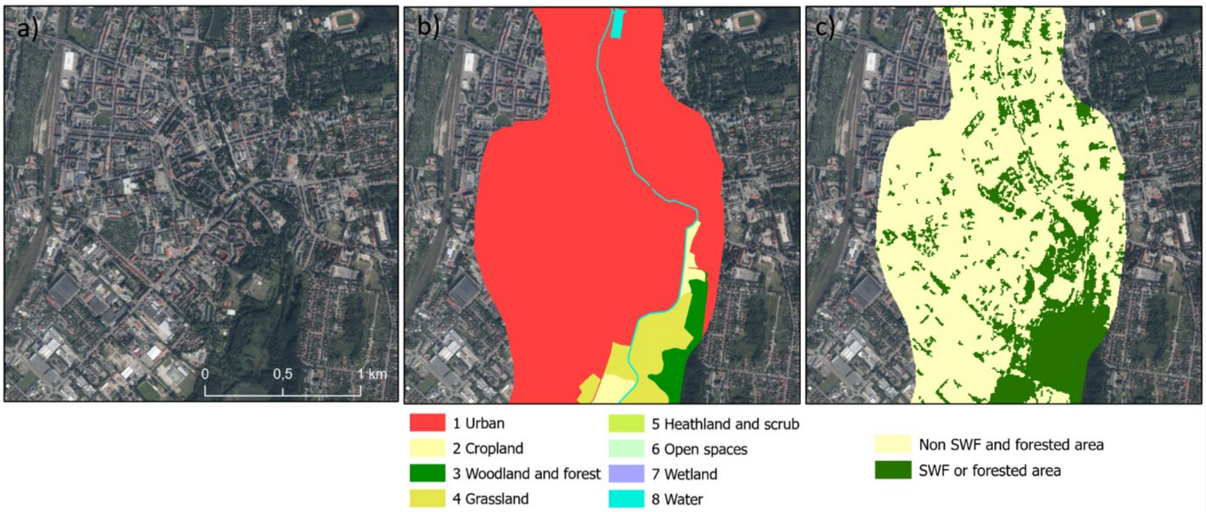


Figure 13: Urban area: (a) aerial orthophoto, (b) Riparian Zones classes – 1st level of detail and (c) merged Small Woody Features and Forest Mask classes.

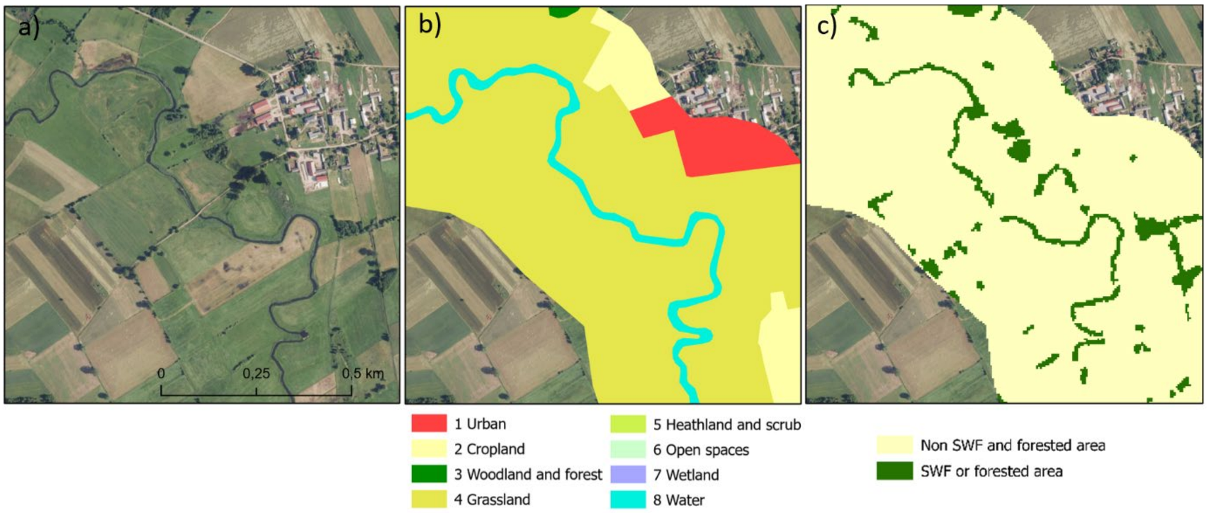


Figure 14: Small river: (a) aerial orthophoto, (b) Riparian Zones classes – 1st level of detail and (c) merged Small Woody Features and Forest Mask classes.

4.4 Comparing RZ 2012-2018 LC/LU change layer with national orthophotos for Poland

Table 13 summarises the Riparian Zones 2012-2018 LCLU changes for Poland. There are 54 change types at level 1, and 275 change types at level 2. By far, the largest LCLU change types occupied between class 3 Woodland and forest to class 3 Woodland and the forest changes covered area of 178.81 km^2 (41 % of the changes). It may be confusing that class 3 is changing to class 3, but this reflects changes at lower levels in the classification hierarchy, so, in this case, from one type of forest to another. If we look into the details, we find that most of the change within the Woodland and forest class was from sub-class 32 Coniferous forest to sub-class 34 Transitional woodland and scrub (108.97 km^2). The second largest type of LCLU changes was related to change from class 4 Grassland to class 1 Urban, occupying 59.02 km^2. The third largest area of changes was associated with the changes from class 2 Cropland to class 1 Urban (35.51 km^2) and from class 1 Urban to class 1 Urban (25.28 km^2). The rest of the LCLU change types cover less than 14 km^2.

Additionally, the attempt to verify the accuracy of the delineation and classification of the RZ 2012-2018 change layer was conducted. However, due to the lack of information on the exact date of image acquisition used for the RZ_2012 and RZ_2018, the verification against the national orthophotos was difficult, in particularly in the areas subject to the dynamic interannual changes. The metadata on the Copernicus webpage (updated 2021) states that the temporal extent of RZ_2012 was 2010 to 2014, whilst that of RZ_2018 was 2017 to 2018. On the other hand, the availability of the national orthophotos was also limited. The national orthophotos were obtained in the period 2010-2013, which refers to RZ 2012, and years 2017-2020 refers to RZ 2018. Examples presented below illustrate difficulties in verification of the RZ changes using the national reference aerial orthophotos.

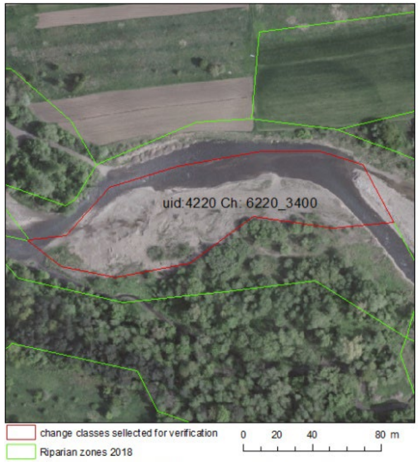
Table 13: Summary of the classes area [km²] of the Riparian Zones 2012-2018 change layer for Poland. Total area 432.6 km².

Poland		Riparian Zones 2018							
		1	2	3	4	5	6	7	8
		Urban	Cropland	Woodland and forest	Grassland	Heathland and scrub	Open spaces with little or no vegetation	Wetland	Water
Riparian Zones 2012	1 Urban	25.28	1.57	5.46	13.66	1.67	0.04	0.01	9.72
	2 Cropland	35.51	2.43	2.07	1.78	-	0.01	0.01	8.10
	3 Woodland and forest	10.26	5.46	178.81	7.30	-	0.61	0.25	3.43
	4 Grassland	59.02	5.99	10.40	0.88	-	0.41	0.25	11.15
	5 Heathland and scrub	0.32	0.01	0.03	-	-	-	-	0.04
	6 Open spaces with little or no vegetation	0.18	-	5.25	0.48	-	-	0.65	1.98
	7 Wetland	1.07	1.03	0.23	1.86	0.03	0.07	0.04	5.89
	8 Water	2.32	0.16	2.12	1.03	0.07	2.65	2.62	0.92

Table 14: Summary of the number of polygons of Riparian Zones 2012-2018 change classes for Poland.

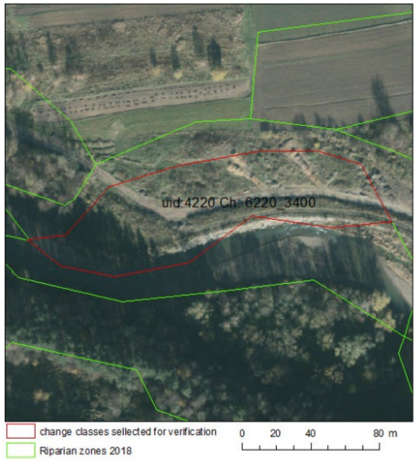
Poland		Riparian Zones 2018								
		1	2	3	4	5	6	7	8	
		Urban	Crop-land	Wood-land and forest	Grassland	Heath-land and scrub	Open spaces with little or no veg.	Wetland	Water	Total no. polygons
Riparian Zones 2012	1 Urban	1 571	97	178	618	53	8	1	393	2 919
	2 Cropland	2 351	100	91	97	-	3	1	272	2 915
	3 Woodland and forest	1 011	199	8 243	292	-	94	10	367	10 216
	4 Grassland	4 530	174	329	47	-	34	7	638	5 759
	5 Heathland and scrub	31	1	1	-	-	-	-	2	35
	6 Open spaces with little or no vegetation	16	-	320	25	-	-	8	276	645
	7 Wetland	77	20	7	26	3	4	2	109	248
	8 Water	217	10	178	81	6	322	146	24	984
	Total no. polygons	9 804	601	9 347	1 186	62	465	175	2 081	23 721

1. Change of riverbanks (6220) into transitional woodland and scrub (3400)



2013
Delineation: partially correct

Classification: partially correct



2017
Delineation: correct

Classification: correct

2018
Delineation: partially correct

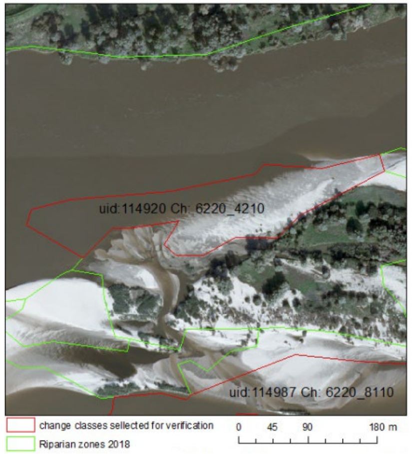
Classification: incorrect

2019
Delineation: incorrect

Classification: incorrect

In general, in the RZ_2012 product the polygon delineation and classification are partly correct (change includes water, class 8100). However, due to a lack of information on exact date of the satellite image acquisition used for the delineation of RZ polygons it was not always possible to find matching reference orthophoto. Most probably delineation of the RZ_2018 feature has been done correctly, based on 2017 reference material, although the area marked as change looks more like semi-natural grassland (4210) than scrub. Nature of change: natural river meandering

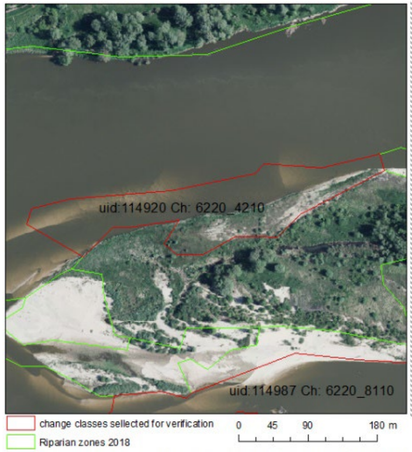
2. Change of riverbanks (6220) into semi-natural grassland (4210)



2010

Delineation: partially correct

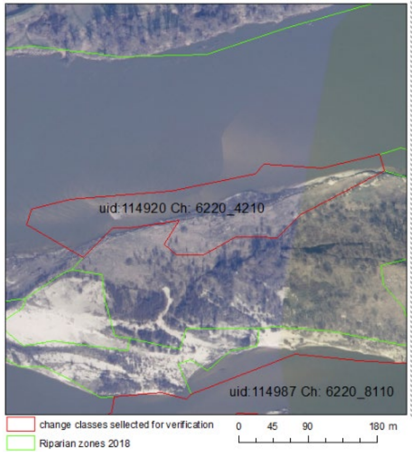
Classification: partially correct



2017

Delineation: partially correct

Classification: partially correct



2020

Delineation: partially correct

Classification: partially correct

Delineation of RZ_2012 and RZ_2018 can be considered partially correct. The changes along the river sandbar are very dynamic, prone to water level fluctuations and flood events. <u>Nature of change:</u> fluvial processes (natural or human induced, e.g. dredging) and natural succession.

3. Change of riverbanks (6220) into inland marshes (7110)

2012

Delineation: correct

Classification: correct

2018

Delineation: partially correct

Classification: partially correct

2019

Delineation: partially correct

Classification: partially correct

2020

Delineation: partially correct

Classification: partially correct

In 2012 the change delineation is correct, however the delineation of the upper polygon in RZ_2012 do not correspond to the situation on ground (water misclassified as classified as riverbank), this id due to the movement of the river bar subject to fluvio-morphological processes and natural succession. It is probably cause by not perfect match between satellite image used for the RZ_2012 and national orthophoto. Nature of change: fluvial processes (river bars aggradation process), natural succession.

4. Change of Bare rocks, outcrops, cliffs (6310) into Inland marshes (7110)

2013
Delineation: partly correct

Classification: incorrect (shallow water with islands, should be delineated as two classes and classified as Inland marshes, 7110 and freshwater, optionally riverbanks, 6220 depending on hydrological stage)

2017
Delineation: correct

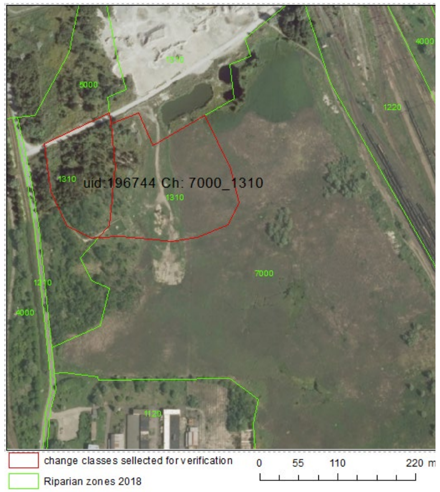
Classification: partially correct (part of the class could be vegetation standing in shallow water)

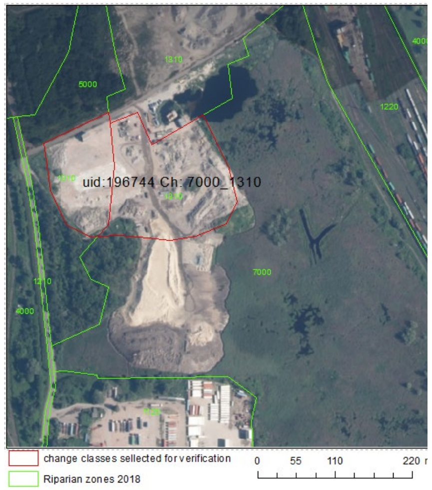
2018
Delineation: correct

Classification: partially correct (see 2017)

This is a lowland reservoir that may undergo natural and artificial water fluctuations. The assessed polygon (uid: 4473) is located in a backwater area of a lowland reservoir that naturally undergoes intensive accumulation processes and following vegetation succession. The RZ_2012 delineation and classification verification based on the 2013 orthophoto gives a partly correct result indicating a later phase of succession. Therefore, the delineation of Inland marsh in RZ_2018 seems correct based on the available reference material. However, the guideline does not specify whether water-based reeds should be included into the water or marsh ecosystem, leading to imprecise delineation of LU/LC classes. It is also ambiguous whether floating vegetation should be included into the class. Nature of change: fluvial processes (river delta / backwater area aggradation) and natural vegetation succession.

5. Change of Wetlands (7000) into Mineral extraction, dump and construction site (1310)





2013

Delineation: partially correct

Classification: partially correct (parts of dry land with grass and trees included)

2019

Delineation: correct

Classification: correct

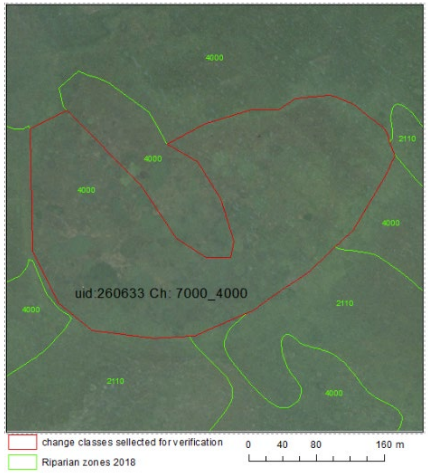
2020

Delineation: partly correct (area below the polygon not included)

Classification: correct

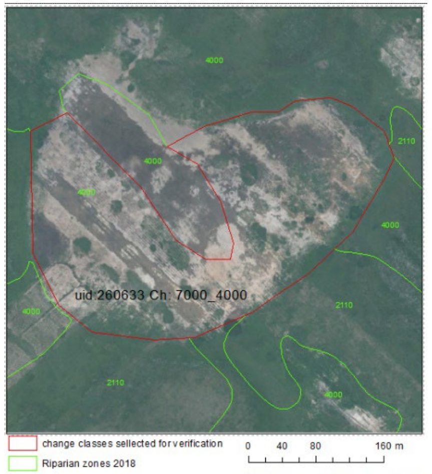
Considering the 2019 and 2020 reference images the delineation should have been much larger, indicating a dynamic process of land reclamation. This indicates a change of a very dynamic nature. The 2018 delineation indicates a different type of change, which is not visible in the later images. <u>Nature of change:</u> anthropogenic land reclamation

6. Change of Wetlands (7000) into Grassland (4000)



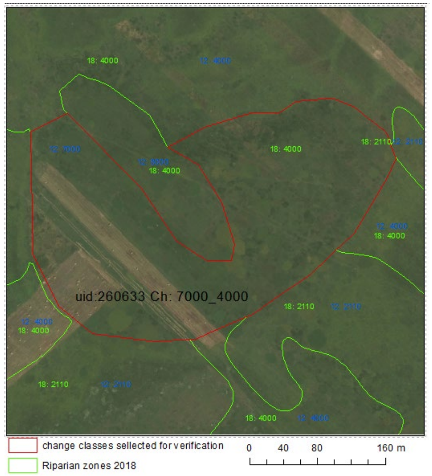
2010
Delineation: correct

Classification: correct



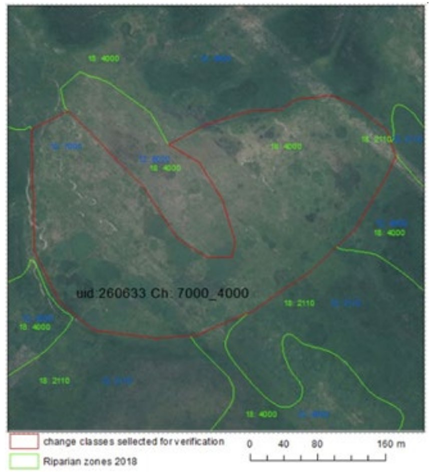
2012
Delineation: correct

Classification: incorrect (it seems rather as a temporary flooded basin than a regular wetland, which is confirmed by following and previous images)



2013
Delineation: correct

Classification: incorrect (should be rather classified as Semi-natural grassland, 4210, according to guideline)

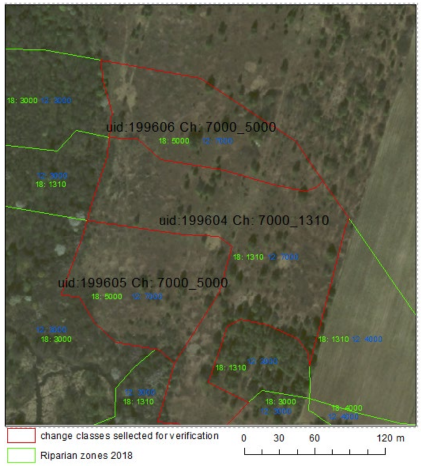


2018
Delineation: correct

Classification: correct

The RZ_2012 classifies the area as wetland. This class includes among others "Grasslands highly wet or flooded at least six months a year". Otherwise, such an area should be included into Managed or semi natural grassland (4100/421x). The reference image from the year 2012 (acquired at spring, in May) indicates different moisture conditions than the surrounding area. In the year 2013 and 2018 indicate semi natural or some managed grassland areas within the class. The delineated change is incorrect because it should be identified as a temporarily flooded area or should not be identified as change. Nature of change: No real change of land use, rather moisture condition variation between years caused an incorrect change in classification.

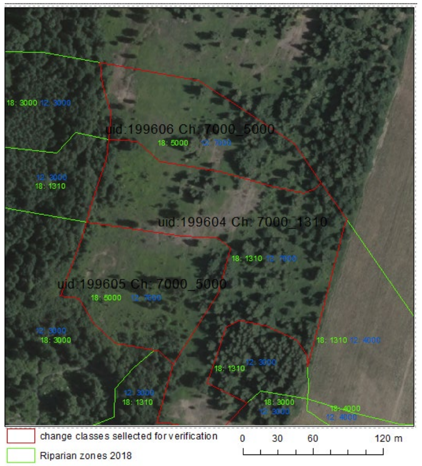
7. Change of Wetlands (7000) into Heathland and scrub (5000)



2012

Delineation: correct

Classification: correct



Earlier than 2017

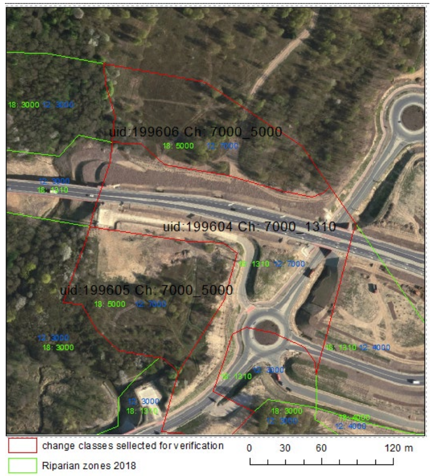
Delineation: correct

Classification: correct

2018

Delineation: correct

Classification: correct



2019

Delineation: partially correct

Classification: partially correct

RZ_2012 classification is probably correct based on the available image from 2012, and the RZ_2018 classification also seems correct based on images from 2017 and 2018, however, the classification becomes increasingly incorrect for images from 2019 due to progressing land use change.

Nature of change: anthropogenic land use conversion of primary probably swampy, river-related land into road-side area. However, before road-building the land could have already been drier due to catchment hydrological processes.

8. Change of Inland marshes (7110) into Mineral extraction, dump and construction site (1310)

2012

Delineation: incorrect

Classification: incorrect (grassland)

2017

Delineation: incorrect

Classification: correct

2020

Delineation: incorrect

Classification: correct

Grasslands in RZ_2012 are incorrectly classified as inland marshes and the polygon is not homogeneous in terms of land use. RZ_2018 delineation and classification seem correct owing to the fact that in the 2017 image its delineation is almost exactly correct, and in 2020 it exceeds the polygon extent. <u>Nature of change:</u> anthropogenic process of land conversion.

To summarise, due to the unknown time of acquisition of satellite images used for the delineation of RZ classes it is not possible to verify the RZ and changes with high confidence. It is particularly problematic along the river corridor. This limits the usability of the layers for monitoring the dynamic character of changes.

4.5 Comparing RZ extent with national flood maps for Poland

The area of overlap between the Riparian Zones and the national flood maps for Poland is presented in Figure 15. There are areas where a large proportion of the 100-year flood zone area is found outside of Riparian Zones. There are also areas, where the RZ overlap with the 100-year flood zone.

Figure 16, shows the results of an overlay including both the 100-year flood zone and the estimated extent of land that would be flooded if the floodgates were to break, which more accurately depicts the extent of the potential floodplain of rivers.

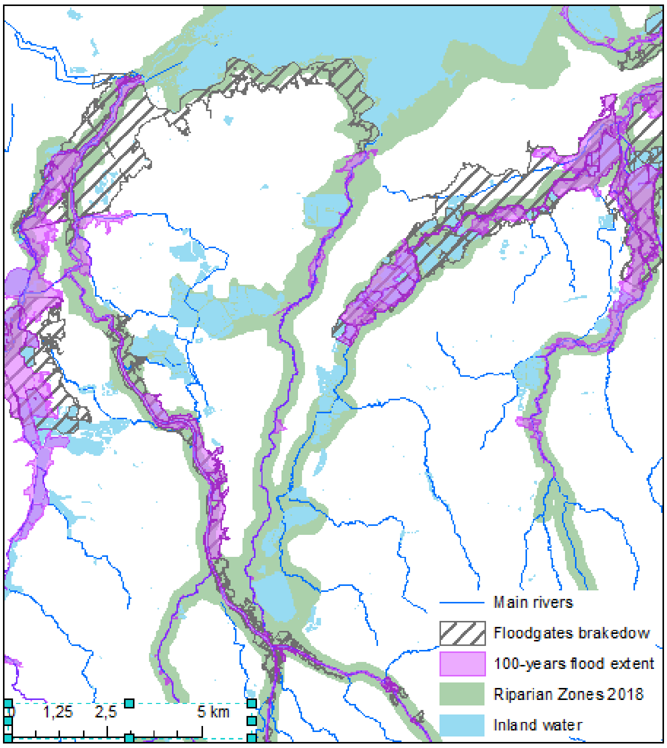


Figure 15: Riparian Zone layer in comparison with 100-years flood extent and floodgates breakdown scenario extent. RZ usually covers a wider buffer along rivers, including valley side-reservoirs (such as fishery ponds).

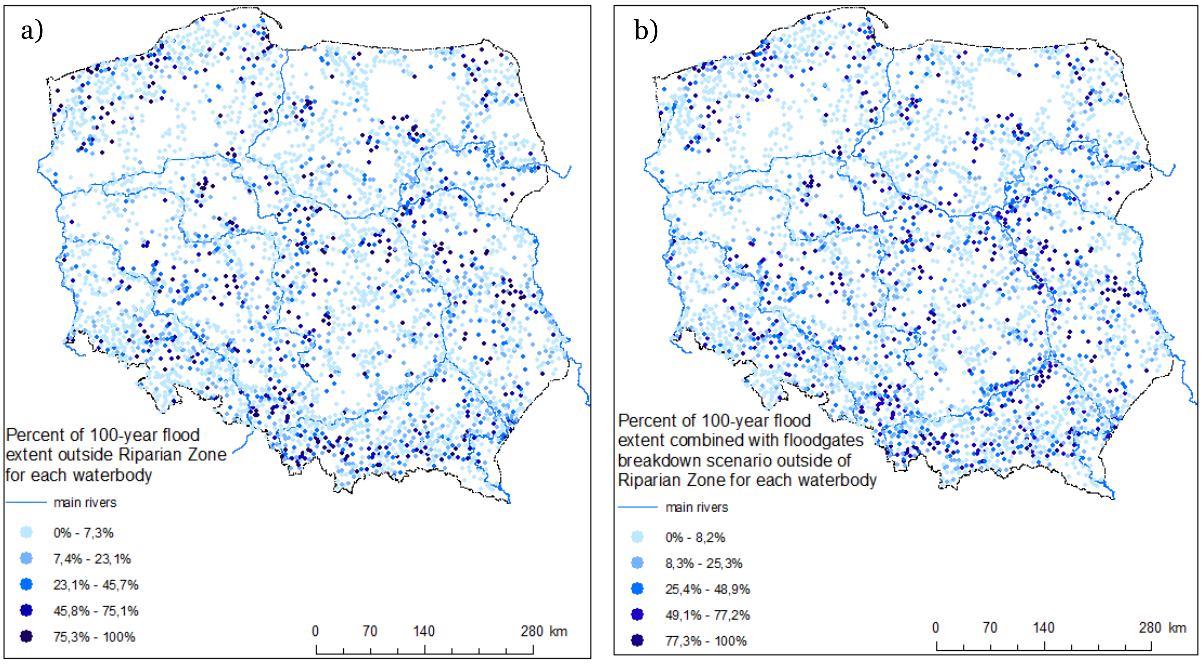


Figure 16: Percentage of a) 100-year flood zone area and b) flood zone area (100-year flood zone and floodgates breakdown scenario area) found outside of Riparian Zones, for each "waterbody" (a water management unit). The floodgates breakdown scenario is the estimated extent of land that would be flooded if the floodgates were to break, which more accurately depicts the extent of the potential floodplain of rivers.

4.6 Comparing RZ 2018 with the Area Frame Survey for Norway (AR18x18)

The overlay between RZ and AR18x18 showed good user accuracy (Table 15) for the classes Water (95.6 %), Woodland and forest (where the various forest categories of AR18x18 accounted for a total of 88.9 %), and Cropland (88.4 % if we include both Cultivated land and Pastures). It seems reasonable to accept that the pastures mapped in AR18x18 could be accurately defined as Cropland according to the RZ definitions, either because they are quite intensively managed, like a fodder crop, or because they occur in a mosaic of other farmland. In RZ, a mix of arable land and pastures is defined as belonging to Heterogeneous agricultural areas (2.3.2.0) under Cropland. The occurrence of boreal deciduous forest and spruce forest in the Cropland class is more difficult to explain.

Just over half of the RZ class Urban corresponded with Built-up areas in AR18x18. Again, boreal deciduous forest and spruce forest were major sources of error, and 12.9 % of the class fell on cropland.

The RZ grassland class showed very little correspondence with the grassland categories in AR18x18. The largest portion (40 %) fell on cultivated land, whilst a total of 24 % fell within various types of forest. However, the grassland class of RZ includes managed grassland, which is difficult to distinguish from cultivated grassland (cropped to provide winter fodder). The RZ Nomenclature Guideline (Tamame et al. 2021) states that confusion can be expected between these classes.

Around half of RZ Heathland and scrub corresponded with expected classes in AR18x18, whilst 13.2 % fell on Boreal deciduous forest, and 10.5 % on Wetland. 7.9 % of this class fell on Alpine meadow communities, which we would expect to be classed as Grassland, and 11.6 % fell on classes that we would expect to be Open spaces with little or no vegetation.

The RZ class Open spaces with little or no vegetation was the class that seemed most inaccurate compared with AR18x18. Only a quarter of the area seemed correctly classified, whilst half of this class fell on categories that we would have expected to be classified as Heathland and scrub. 13.3 % fell on various types of forest.

The user accuracy of RZ Wetland reached 69 % if Peatland forest was considered accurate. The 13.3 % falling on other types of forest and 10 % on Alpine heath were the greatest sources of error.

Table 15. User accuracy: the percentage distribution of each Riparian Zone class amongst the Area Frame Survey (AR18x18) classes, where 100 % is the total area in the RZ class (column sums). Coloured cells show the expected correct correspondence between classes.

	Riparian Zones								
AR18x18	Urban	Crop-land	Wood-land & forest	Grass-land	Heath-land & scrub	Open space with little/no vegetation	Wet-land	Water	Total
Built-up areas	54.8	1.7	0.4	7.3	0.2	0.6	0.3	0.1	1.9
Cultivated land	12.9	83.2	1.0	40.5	0.0	0.0	0.1	0.1	6.4
Pastures	3.3	5.2	0.7	23.3	0.3	0.0	0.2	0.0	1.1
Boreal deciduous forest	12.0	4.6	34.0	9.7	13.2	6.1	8.0	1.1	17.4
Broadleaved deciduous forest	0.5	0.1	0.6	0.5	0.0	0.0	0.0	0.0	0.3
Pine forest	7.1	0.9	21.4	3.2	0.8	2.7	4.0	0.4	9.6
Spruce forest	8.1	3.1	25.9	8.1	1.4	0.7	1.3	0.5	11.5
Peatland forest	0.5	0.5	7.1	2.4	1.2	3.7	10.5	0.3	4.2
Alpine meadow communities	0.0	0.0	0.2	0.9	7.9	2.5	1.7	0.2	1.3
Alpine heath communities	0.0	0.0	3.1	0.0	48.7	44.7	10.0	0.4	9.9
Non-forested dry land below the treeline	0.1	0.0	0.2	2.2	2.8	5.2	1.3	0.1	0.8
Snow-bed vegetation	0.0	0.0	0.0	0.0	8.8	9.8	2.1	0.1	1.7
Non-productive areas	0.2	0.0	0.6	0.5	2.8	16.0	0.1	0.3	1.3
Wetlands	0.1	0.2	3.8	0.3	10.5	4.0	58.5	0.8	7.9
Freshwater	0.5	0.5	1.1	1.0	1.4	4.0	2.0	95.6	24.7
	100	100	100	100	100	100	100	100	100

Regarding Producer accuracy (Table 15), the picture was quite similar, with relatively good results for Freshwater, Forest and Built-up areas.

Although a lower proportion (69.2 %) of Peatland forest was classified as forest in RZ, 20 % of this type was classified as wetland, which can be considered accurate. Peatland forest includes bog forest and swamp forest, and these forest types are described together with wetland in the AR18x18 guidance for vegetation mapping (Rekdal & Larsson 2005). The classes are also placed close to each other in the AR18x18 system (Peatland forest is class 8, Wetland is class 9).

Regarding the details of the forest categories, we also examined results at level 2 of the RZ classification system and found that around half of the AR18x18 boreal deciduous forest was classified as 3.1 Broadleaved forest. And just over half of Pine and Spruce forest was classified as 3.2 Coniferous forest. Incorrectly classified were 14.5 % of AR18x18 deciduous that were classified as RZ coniferous, and 7 % of Pine and Spruce forest that were classed as RZ deciduous. However, the 11 % of deciduous and 18 % of coniferous falling in the class 3.3 Mixed forest cannot really be judged to be more or less accurate than the AR18x18 classes, since the AR18x18 mapping system does not include a category for mixed forest and our analysis did not take account of mosaics of vegetation types from AR18x18. Similarly, we have no good control of the class 3.4 Transitional woodland & scrub, since the forest state is not recorded in AR18x18. Nevertheless, it seems reasonable that a higher proportion of Pine and Spruce forest (12 %) were in a transitional state, compared with boreal deciduous forest (1.7 %), since Pine and Spruce are the main species used in forestry.

The producer accuracy for Built-up areas (75.6 %) was higher than the user accuracy for Urban (54.8 %). This reflects the fact that Urban was overestimated in the RZ dataset. Whilst 1.9 % of the overlay area was AR18x18 Built-up area, 2.7 % of the total area was classed as RZ Urban, due to the misclassification of forest and cropland as Urban.

The majority (78.2 %) of cultivated land was identified accurately as cropland. Since cultivated land in Norway is often a grass fodder crop the classification of 10 % to Grassland cannot be considered inaccurate. The AR18x18 class Pastures was also split between these two RZ classes, although with slightly more in the Grassland class (33 %) than the Cropland class (28 %). Almost as large an area (25.5 %) was classed as Woodland and forest. This discrepancy may also reflect differences between classification systems, since many Norwegian pastures are irregularly shaped, surrounded by forest and include small, wooded elements. Therefore, these differences in classification could be due to mapping rules and definitions, rather than true inaccuracies in the identification of the land cover/use.

When it comes to Alpine meadows, heathland and open space with little or no vegetation, the correspondence between the AR18x18 dataset and RZ is much lower. Most meadows fall in the RZ heathland class (not Grassland), as does most Snow-bed vegetation (not, as expected, Open space with little or no vegetation). Around half of heathland is correctly classed as heathland, but significant proportions are classed as Woodland & forest, Open space with little or no vegetation or Wetland. Around half of Non-productive areas in AR18x18, which includes barren land, boulder fields, exposed bedrock and glaciers, correspond with Open space with little or no vegetation in RZ. Significant proportions are classed as Heathland & scrub and Woodland & forest. These two RZ classes also cover large proportions of Ar18x18 wetlands.

Table 16. Producer accuracy: how often the land types in AR18x18 are correctly shown in the Riparian Zones dataset, i.e. the percentage distribution of each AR18x18 class among the RZ classes, where 100 % is the total area in the AR18x18 class. Coloured cells show the expected correct correspondence between classes.

	Riparian Zones								
AR18x18	Urban	Crop-land	Wood-land & forest	Grass-land	Heath-land & scrub	Open space with little/no vegetation	Wet-land	Water	Total
Built-up areas	75.6	5.3	8.2	6.0	1.0	1.3	1.4	1.2	100
Cultivated land	5.3	78.2	6.0	10.1	0.0	0.0	0.1	0.2	100
Pastures	7.9	28.2	25.5	33.1	3.4	0.0	1.3	0.7	100
Boreal deciduous forest	1.8	1.6	79.9	0.9	9.2	1.4	3.7	1.5	100
Broad-leafed deciduous forest	4.8	1.2	89.4	2.8	0.0	0.0	0.0	1.8	100
Pine forest	2.0	0.6	90.5	0.5	1.0	1.1	3.3	1.0	100
Spruce forest	1.9	1.6	91.7	1.1	1.5	0.2	0.9	1.1	100
Peatland forest	0.3	0.8	69.2	0.9	3.6	3.6	20.0	1.7	100
Alpine meadow communities	0.0	0.0	5.2	1.1	71.9	7.3	9.9	4.6	100
Alpine heath communities	0.0	0.0	12.9	0.0	59.8	18.2	8.1	1.0	100
Non-forested dry land below the treeline	0.2	0.2	12.1	4.3	42.3	25.6	12.6	2.8	100
Snow-bed vegetation	0.0	0.0	0.0	0.0	64.4	23.5	10.0	2.0	100
Non-productive areas	0.5	0.0	17.4	0.6	26.0	49.5	0.8	5.2	100
Wetlands	0.0	0.1	19.6	0.1	16.3	2.0	59.3	2.5	100
Freshwater	0.0	0.1	1.9	0.1	0.7	0.6	0.6	95.9	100
Total	2.7	6.1	40.8	1.6	12.1	4.0	8.0	24.7	100

4.7 Comparing RZ 2018 with other national data for Norway

Whilst the AR 18x18 dataset described above is the best ground truth available for Norway, we also did a quick "look and see" against other national data, including orthophotos and maps of the 3Q Monitoring Programme for Agricultural Landscapes. In Figure 17 we compare orthophoto and Riparian Zone level 1 classification. We clearly see a line of trees along the north-western side of the river that is not captured in RZ. On the other side of the river, we see a line of bushes or small trees along the whole river, again not included in RZ. Figure 18 shows that the 3Q Monitoring Programme captures narrow strips of vegetation along streams, as opposed to RZ. RZ also misses minor roads and settlements. It should be noted that 3Q is based on detailed manual interpretation of orthophotos. The length of edges between adjacent RZ polygons (level 1 classification) shown in Figure 19, are summarized in Table 16. In decreasing order, the length of edge between Water and Cropland is 14 044 m, Water and Woodland and forest is 4 426 m, Water and Urban is 4 164 m, and Water and Grassland is 1 363 m. The orthophoto suggests that there exists more vegetation along streams and waterways than captured in RZ.

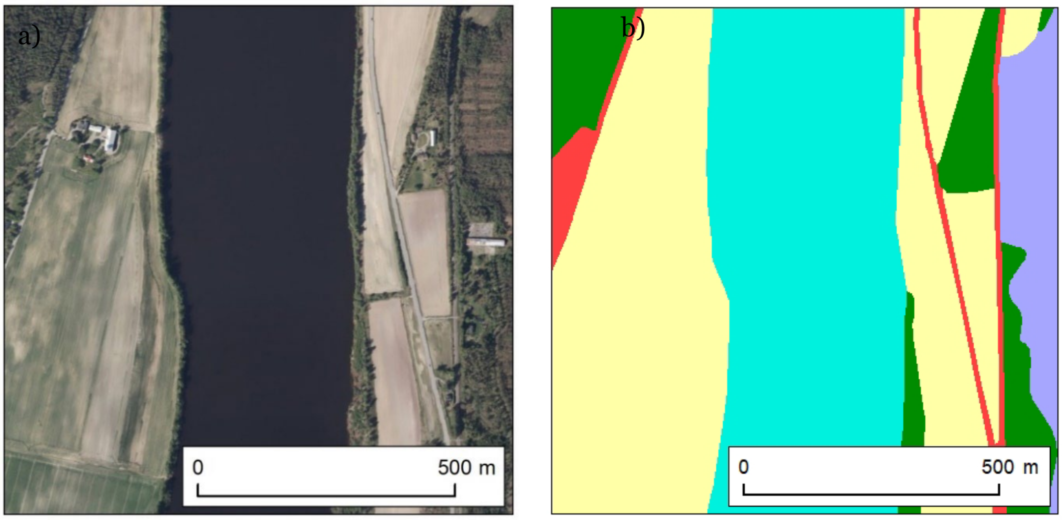


Figure 17: a) Aerial photo, b) Riparian Zone level 1 classification.

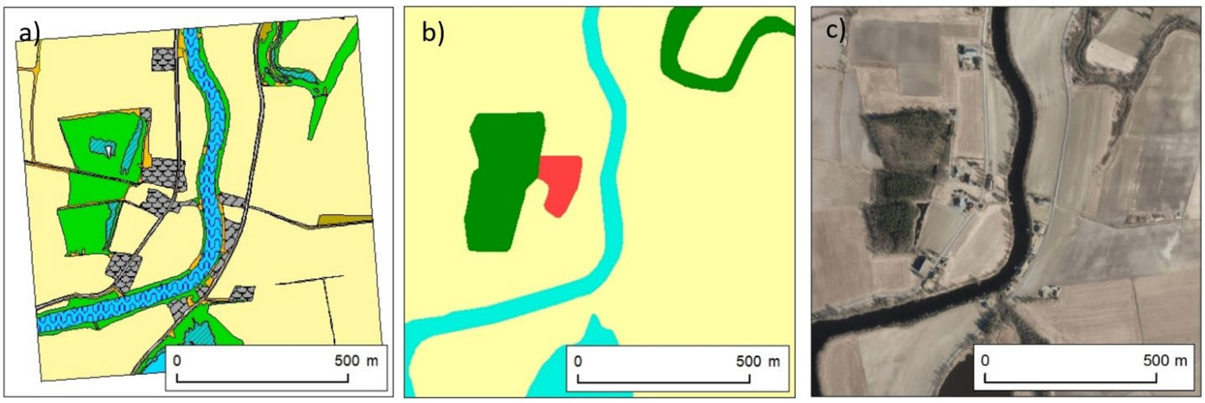


Figure 18: a) Detailed classification from aerial photos, from the 3Q Monitoring Programme, b) Riparian Zone level 1 classification (water in blue, farmland yellow, forest green, urban red), and c) aerial photo. The RZ dataset misses small built-up areas (grey in map a).

Figure 19: a) Riparian Zone level 1 classification, b) aerial photo.

Table 17: Length of adjacent edges between neighbouring polygons, summarized by Riparian Zone level 1 classes. Bold highlights edges along water. Sum length = 103 446 m.

RZ Level 1	RZ level 1	Length (m)	Percentage
Urban	Cropland	26 133	25.3
Urban	Woodland and forest	18 839	18.2
Urban	Grassland	4 877	4.7
Urban	Wetland	1 185	1.1
Urban	Water	4 164	4.0
Cropland	Woodland and forest	22 618	21.9
Cropland	Grassland	1 250	1.2
Cropland	Water	14 044	13.6
Woodland and forest	Grassland	2 208	2.1
Woodland and forest	Wetland	1 912	1.8
Woodland and forest	Water	4 426	4.3
Grassland	Wetland	427	0.4
Grassland	Water	1 363	1.3

4.8 Comparing RZ extent with national flood maps for Norway

4.8.1 100-year flood zone map

An overlay between RZ 2018 and the 73 river segments where a 100-year flood zone has been calculated showed that on average 10.9 % of the 100-year flood zones fell outside the Riparian Zone extent. Figure 20 illustrates the overlay procedure and results for one of the river segments. The average result conceals differences between the different segments and Figure 21 shows that there was considerable variation across Norway.

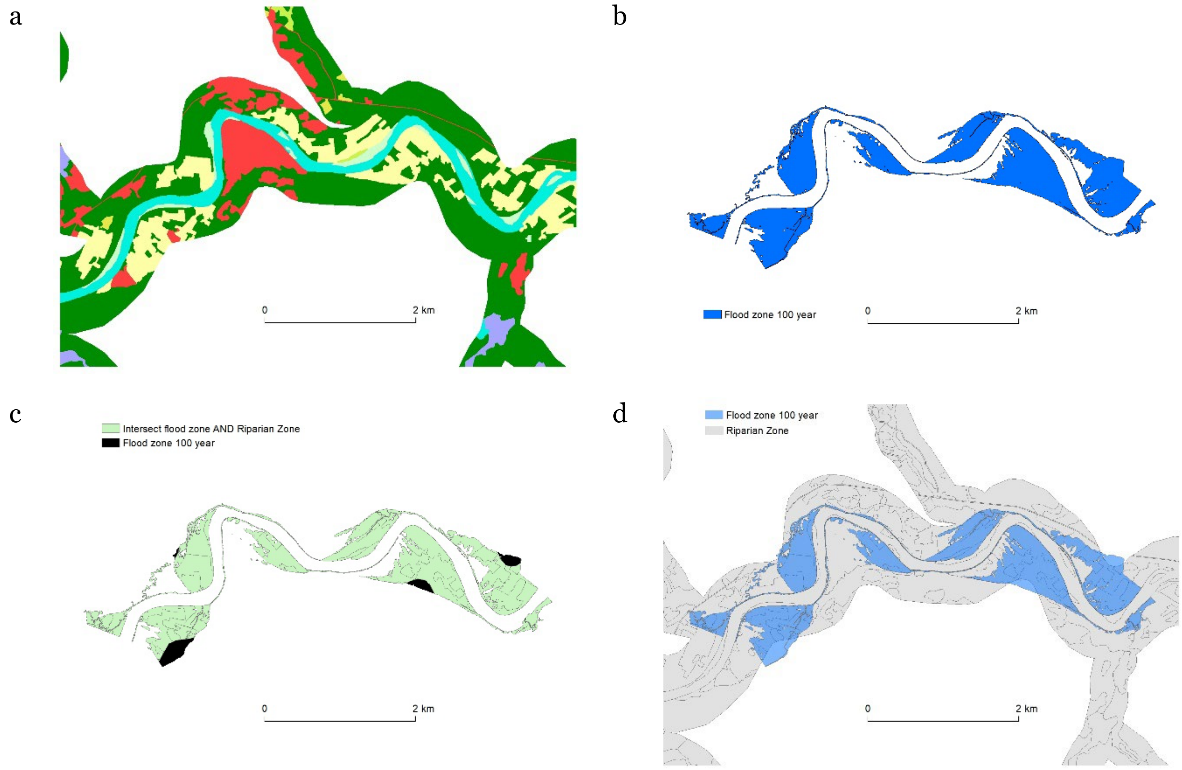


Figure 20: a) Riparian Zone, b) River segment for which a 100-year flood zone has been calculated c) Intersect of Riparian Zone and flood zone (green) and areas of flood zone outside Riparian Zone (black), d) Flood zone displayed (transparent blue) above Riparian Zone.

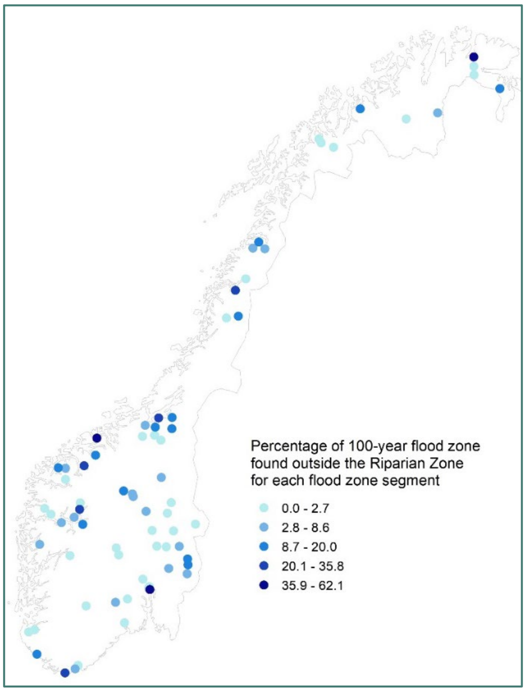


Figure 21: The 73 river segments where a 100-year flood zone has been calculated, and the percentage of the 100-year flood zone that falls outside the Riparian Zone delineation.

4.8.2 Flood awareness map ("aktsomhetskart")

The difference between the awareness map and the Riparian Zone map for a river segment is shown in Figure 22. In this example, the awareness map resembles the Riparian Zone map to a degree. This is promising but looking at a larger extent (Figure 23), we see a considerable mismatch between the datasets. Generally, it appears that the largest rivers are captured by RZ 2018, whilst the smallest rivers are not. For medium sized rivers, some are included and others not.

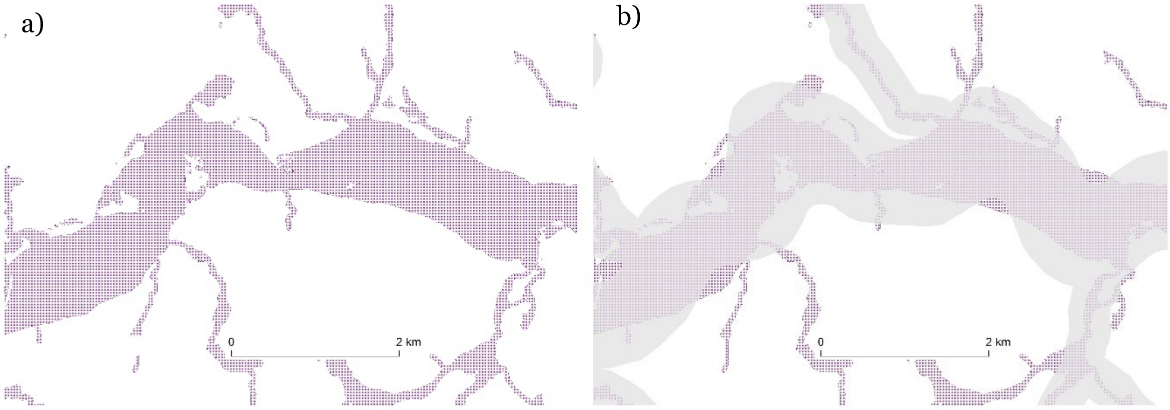


Figure 22: a) Flood awareness map showing the same river segment and extent as Figure 20, b) Riparian Zone (transparent grey) overlaid Flood awareness map (purple).

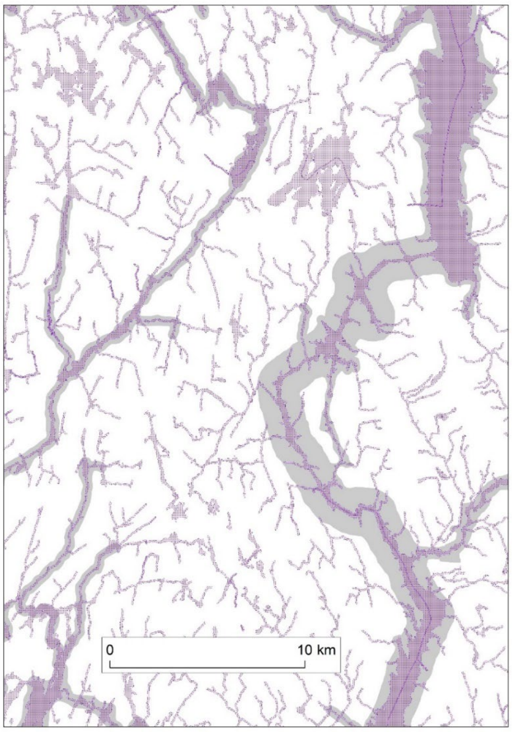


Figure 23: Flood awareness map (purple) with Riparian Zone (grey transparent) below.

4.9 RZ 2012-2018 change layer Norway

Table 17 summarises changes in land cover/land use, from the Riparian Zones 2012-2018 change layer for Norway. As for Poland, by far the largest area of change was from 3 Woodland and forest to 3 Woodland and forest, covering 86.1 % of the changes. Again, these changes within the forest are primarily from sub-class 32 Coniferous forest to sub-class 34 Transitional woodland and scrub, reflecting forestry activities.

The row with change from class '0' to the other classes means that the 2018 RZ layer has a larger extent than the 2012 layer. A visual inspection tells us that these areas are river segments, not scattered polygons.

Table 18: Summary of the classes area [km2] of the Riparian Zones 2012-2018 change layer for Norway. Total area 428.9 km2.

		Riparian Zones 2018							
		1	2	3	4	5	6	7	8
		Urban	Crop-land	Wood-land & forest	Grass-land	Heath-land & scrub	Open spaces with little/no vegetation	Wetland	Water
Riparian zones 2012	0	-	-	5.5	0.0	6.3	0.6	2.7	1.2
	1 Urban	1.9	0.6	0.0	0.6	0.0	0.1	-	0.0
	2 Cropland	4.3	0.1	0.2	0.0	-	-	-	0.0
	3 Woodland and forest	26.2	2.5	369.4	0.6	-	0.4	0.1	0.3
	4 Grassland	1.7	0.1	0.1	0.0	-	0.0	-	0.0
	5 Heathland and scrub	0.8	0.0	0.1	0.0	-	0.1	-	0.0
	6 Open spaces with little or no vegetation	0.1	-	0.0	-	-	0.2	-	0.3
	7 Wetland	0.6	0.0	0.2	0.0	-	0.0	-	0.2
	8 Water	0.2	0.0	0.0	-	-	0.4	0.0	-

Figure 24 shows the location of change polygons for the whole of Norway highlighting urbanization changes (change to Urban from any other class). Changes to Urban land use affected 8 % of the area registered as having changed.

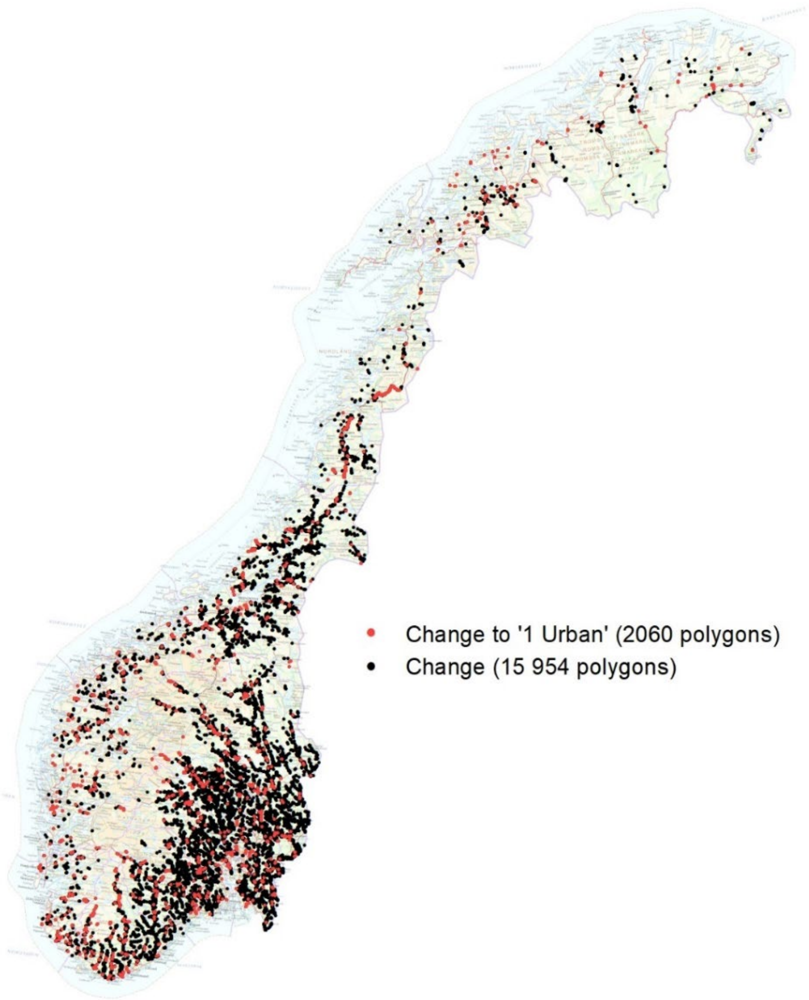


Figure 24: Map of Norway with all changes in the Riparian Zone change layer marked as dots (15 954 change polygons). Red dots are changes to class 1 Urban, while black dots denote other changes.

The verification task carried out for Poland, described in section 4.4, highlighted that verification of the RZ Change 2012-2018 dataset is virtually impossible due to the lack of information about the date of the source images. Since this is already documented, with case examples of the types of errors involved, we do not include more examples here. Instead, we include a case example of how the change data might be used, if – in the future – it can be verified.

4.9.1 A case study: Tana River, Norway

We present a case where we look at change summarised for a river district. The case was selected because information was available from 2014 about the types of change expected (Hansen et al. 2014). The Tana River is situated in Northern Norway, running along the border with Finland for 280 km (Figure 25). Tana river is the largest and most productive salmon river in both Finland and Norway that is still in a relatively natural state and is therefore of high interest for both Norwegian and Finnish authorities (Hansen et al. 2014). A major focus of the river management has been to re-establish bushes and trees on erosion control constructions along the river. If the RZ dataset is a reliable dataset for monitoring, it could provide data to assess the success of the management activities. We overlaid the Norwegian part of Tana River district with the Riparian Zone Land cover / Land Use Change 2012-2018 dataset to document changes within the district.

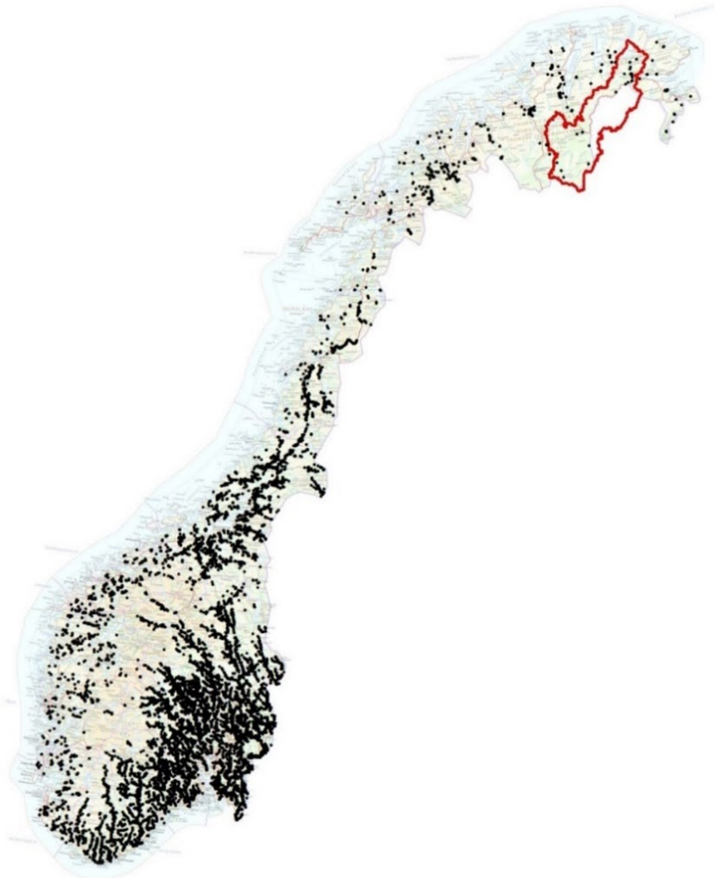


Figure 25: Tana River District (red) on a map of Norway with all changes in the Riparian Zone change layer marked as a black dot per change polygon (15 954 change polygons, of which 30 in the Tana river district).

The type of change that affected the greatest area in the Tana River District was from Forest to Urban (44 %), with over half of this due to four occurrences of change to Industrial, commercial or military units (Table 18). The next most common type of change was from forest to Transitional woodland and scrub (34.1 %). There were two changes from forest to wetland (9.2 % of the changed area) and one change in the opposite direction from wetland to forest (5.0 %).

Table 19: Changes occurring in the Tana River District, according to the Riparian Zone 2012-2018 Change layer, at level 4 of the classification system. Results are shown as number of occurrences (no.), area in hectares (ha) and percentage of the total area changed (%).

	2018 Land cover/land use	no.	ha	%
Natural & seminatural broadleaved forest	Dense urban fabric	1	0.2	0.5
Natural & seminatural broadleaved forest	Low density urban fabric	2	1.6	3.5
Natural & seminatural broadleaved forest	Industrial, commercial and military units	4	10.6	23.3
Natural & seminatural broadleaved forest	Road networks and associated land	1	2.5	5.6
Natural & seminatural broadleaved forest	Mineral extraction, dump and construction sites	4	2.0	4.4
Natural & seminatural broadleaved forest	Arable land	2	2.4	5.3
Natural & seminatural broadleaved forest	Transitional woodland and scrub	10	15.6	34.1
Natural & seminatural broadleaved forest	Inland marshes	2	4.2	9.2
Natural & seminatural coniferous forest	Dense urban fabric	1	3.0	6.7
Managed grassland	Low density urban fabric	1	0.2	0.5
Unexploited peat bogs	Transitional woodland and scrub	1	0.9	2.0
Seasonally connected water courses (oxbows)	Natural & seminatural coniferous forest	1	2.3	5.0
Sum		30	45.7	100.0

The areas of change comprised only 0.03 % of the total area of riparian zone. We can nevertheless note that, in relation to the goal to maintain this river in a relatively natural state, most of the changes were negative. Nor was it possible to detect any sign of vegetation re-establishment in the area. Perhaps the bushes and trees in the areas being restored had become tall enough to be classed as Transitional woodland and scrub already in the "2012" data – especially considering that this dataset could include images from 2014 (according to the temporal extent given in the online Metadata). Unfortunately, we do not have independent statistics to allow verification of the RZ Change data, and we do not know the locations of the vegetation re-establishment sites. This could be an interesting follow-up, although, as noted previously, information about the year of source images would be important.

5 Discussion

5.1 Accuracy of the RZ data compared with national datasets

For both Poland and Norway, the accuracy of land cover/land use information in the Riparian Zones datasets was quite good at level 1 for Water, Cropland and Woodland and forest. "Misclassifications" between Cropland and Grassland seemed partially understandable, since managed grassland can be very similar to cultivated forage crops, and the category Heterogeneous agricultural land is a mosaic type that is not used in the national classification systems.

For Urban land use, the user accuracy was poorer, with significant misclassification to the largest category of land use in each country, i.e. Grassland for Poland and Woodland and forest for Norway (each comprising about 40 % of the total RZ area in the respective countries). Also, in both countries, roughly 10 % of Urban was misclassified to Cropland (13 % for Norway and 8 % for Poland). The producer accuracy was higher for both countries, reflecting the fact that Urban was over-estimated in the RZ data. For Poland, the analysis at level 2 showed that large proportion of the Mineral extraction class and Green urban, sport and leisure facilities were underestimated in RZ.

For Poland, where Grassland is the dominant land type, the user accuracy was over 60 % with about 20 % classified as cropland. The analysis at level 2 confirmed that this was mainly due to misclassification of Managed grassland, whilst Natural and semi-natural grassland was more correctly classified. The producer accuracy was slightly higher. For Norway, where Grassland is a very uncommon land type, both user and producer accuracies were very low.

The highest accuracy was obtained for the Woodland and forest class, which is the dominant land type in the RZ in Poland (21 %) and Norway (40 %), however the forest types in the RZ are mixed up. The highest user and producers' accuracy was obtained for the Coniferous forest class (around 63 %).

The accuracies for both Heathland and scrub and Open spaces with little or no vegetation were very poor in both countries. These are uncommon land types in Poland, covering just 0.2 % of the Riparian Zones. However, in Norway they are significant land types, together covering 16.2 % of the total RZ area. The fact that the RZ class includes scrub, probably explains some misclassification to Woodland and Forest. Scattered patches of mountain birch forest, with varying degrees of tree density, are common on heathlands in Norway. Whilst these would be mapped as Boreal deciduous forest in AR18x18, perhaps the mosaic distribution caused them to be placed in the Heathland and scrub category in RZ. Similarly, misclassification between these classes and wetlands could be due to the mosaic occurrence of wetlands. In terms of provision of ecosystem services these differences in classification are not trivial, especially in a river setting where the amount of substrate (bare ground or soil) and the presence or absence of trees are significant in relation to run-off and bank stability. They also provide quite different habitats for biodiversity.

Accuracy was generally lower at level 2 of the classification system, which again may be partly due to differences in definitions in the classification systems, as well as differences in the feasibility of capturing certain elements from the different data sources used. This was perhaps especially obvious with the Norwegian ground truth AR18x18, which was based on field survey. It is not necessarily a problem to have different kinds of maps for different purposes that use different classification systems, however it does make verification more difficult. This challenge was exacerbated by the fact that the RZ products have been developing over time and it wasn't clear which version of the guidelines was used for which dataset (see more on technical issues below). This creates uncertainty about how the classes were created.

Also, whilst the documentation provides descriptions of classes, and some guidelines on which land uses should be included or excluded, the definitions were still not very detailed. The content of each class, especially those related to wetlands, water-dependent ecosystems and natural grassy and scrubby areas are not precise and can open for different interpretations. Both the uncertain semantic content of LC/LU classes together with uncertain feasibility to distinguish certain characteristics based on the applied methodology create sources of error and make verification difficult.

It has also to be noticed that the RZ_2018 contains categories not defined in the documentation, those classes are assigned as class 3.0, 4.0, 5.0 and 8.0 (see Figure 7 and 8) – they are present in Poland and Norway.

5.2 Potential of RZ data for monitoring

Even if the Riparian Zones datasets do not match the national data exactly, they could still be useful if they are calculated consistently from one time period to the next and capture real change. Unfortunately, this most central aspect was impossible to verify from the existing datasets, due to the lack of time stamps in the data and the fact that the data were taken from a reference period of three or four years (for more details about the technical issues, see section below). Of course, many monitoring programmes build on data collection that occurs over multiple years, and this is not problematic in itself. However, before the RZ datasets can be used in monitoring, it is essential that they are verified as reflecting the true situation.

One challenge that is particularly difficult for dynamic river systems, is that the rivers alter their course over time. It is therefore useful that the riparian zones are relatively broad and encompass all possible future paths of the river. On the other hand, it is often the land use directly adjacent to the water that is the most critical in influencing river morphology and chemistry, so for some purposes an analysis of a narrower belt alongside waterways would be more desirable. This could be achieved through a GIS analysis of the RZ data, using a buffer zone along water polygons. However, for this to be meaningful, it is important that the vegetation is mapped at sufficient resolution to accurately reflect land use close to the water's edge.

The visual comparison of RZ with orthophoto and maps from the Norwegian agricultural monitoring programme (3Q), clearly showed that narrow bands of vegetation along the river are not captured in RZ. The minimum mapping width of RZ is 10 m, whilst the minimum mapping width of 3Q, for areas close to agricultural land, is 2 m. In Norway, one of the requirements to be able to receive agri-environmental subsidies is to keep a vegetation zone of at least 2 m between agricultural land and waterways with steady water flow (Lovdata 2022). This zone cannot be tilled. Whereas 3Q is a sample programme, composed of circa 1000 squares of 1 x 1 km to give representative results for Norway, the RZ is a full coverage map of riparian zones. The latter, extending over a much larger area and not dependent on statistics to estimate national figures, would be a useful supplement to 3Q. However, in the case of Norway, the minimum mapping unit in RZ is currently too large and the dataset misses these narrow strips of vegetation that are required in agri-environmental policy.

The Polish analysis of Small Woody Features within RZ also highlighted that many important small features are "overlooked" in RZ. Significant proportions of several open categories in RZ, including 14 % of the Urban area, fell on areas defined as small woody features or forest in the HRL-SWF dataset. This is a consequence of the minimum mapping size being 0.5 ha in RZ, compared with 200 m^2 for patches in SWF, and even smaller for linear features, for which no minimum mapping size is defined. Nevertheless, the detail of the SWF dataset cannot simply be added to analyses of riparian zones since we also saw examples of misclassification in HRL-SWF (e.g. Figure 14). Finding a suitable ground truth to verify SWF is challenging and will be addressed in a separate report of the InCoNaDa project (D4.2). Despite the lower spatial resolution of RZ compared with SWF, it seems that RZ nevertheless provides more detailed information than the existing Polish national data BDOT10K. The RZ subclass Lines of trees and shrubs generally fell on areas of Cropland or Grassland in BDOT10K, which seems correct and suggests that linear features at least are better captured in RZ than in BDOT10K.

In addition to the thematic accuracy and spatial resolution of mapping within riparian zones, another important aspect affecting their usefulness is the delineation of the zones. In Poland, the RZ seems to cover the nationally calculated 100-year flood zones for a majority of water management units, although there are a significant number of units where the whole flood zone is not captured. In Norway, RZ tends to have a wider extent than the 100-year flood zones of the mapped river segments, but here too there are some areas where the 100-year flood zone extends outside of the RZ. Since the flood zone maps are calculated based on local flood statistics and hydraulics, we would not expect the two datasets to be identical. We suspect that the national datasets may encompass broader zones in flatter landscapes, whilst the RZ model may be more conservative in holding to the more immediate buffer along the rivers. Probably the methodology of the Norwegian flood awareness map more closely resembles that of RZ delineation and here we find the RZ generally to be wider than the flood awareness extent. At the same time, we find that smaller rivers are not included in RZ. The overall impression is that the RZ delineation is good enough, considering that the primary purpose is to monitor the land cover/land use in close vicinity to streams and waterways. Probably it would be useful at a national level to include more rivers in the RZ dataset.

We noted in the introduction that municipalities may be required to stipulate the width of the belt of vegetation to be taken into consideration along waterways in connection with development plans and that this width may become legally binding under the Planning and Building Act. Currently the best tool available to help municipalities with this task is the flood awareness map. However, there is no standardised national monitoring of these zones. The RZ data could fill this gap and provide a national control that builders and developers are respecting the regulations. Such a national map would also address issues of fairness since the methodology is standardised and objective. Again, the actual usefulness of course still depends on the thematic accuracy and resolution of the land cover/land use data.

In addition to the obvious use in monitoring, another possible use of the RZ data could be to identify waterside vegetation classes that are poorly mapped in national data sources. An example in Poland would be the identification of reed zones on the borders of larger lakes. This can be done by comparing the class 7110 class (Inland marshes) with the lake delineation extent available from the national databases of highest accuracy. An example is shown in Figure 26.

Figure 26: Reed zone identified as 7110 class (Inland marshes) along a lakeshore (orange line). Lake borders identified with the national hydrological map at scale 1:10 000 (MPHP10), Jeziorak Lake, Poland.

5.3 Technical issues

During the work we encountered various challenges related to the nomenclature and technical specifications of the Riparian Zone datasets.

The investigation of the source datasets, e.g. VHR_IMAGE_2018, revealed that the timelines of a dataset is ± one year, whereas the timelines of the RZ product is a four-year scope, i.e. 2010-2014 for RZ 2012 and 2017-2020 for RZ 2018 respectively. This means, at least in theory, that the RZ Change product could be showing LC/LU change from 4 to, in extreme cases, 9 years, while nominally it should be 6 years over the entire coverage. The usefulness of the LC/LU datasets for local use implies that it is possible to confidently state (or with a known confidence) about the change in LC/LU class, and over what timeframe. In the framework of this study, we initiated an exercise to verify the accuracy of the RZ 2012-2018 change product but discovered that the product and its available metadata does not allow reliable verification due to lack of information about the date of source images. For example, a LC/LU class could be compared with four different national image data sources and its correctness of delineation would depend on which national data product is used (see figures in chapter '4.4 Comparing RZ 2012-2018 change layer with national orthophotos for Poland'). To assess the RZ change layer against orthophotos we need to know the RZ LC/LU class state at a particular moment of time.

The information provided on the webpage and in the RZ products technical documentation[1] indicates that the nomenclature and the data themselves have been modified since the first release. However, the downloaded datasets do not carry any version information, and are available only for the (probably) latest version. We recommend that the version information is included in each dataset for the CLMS products, accompanied by the appropriate technical documentation. We also recommend that all versions of a dataset and its documentation should be freely available.

The technical specifications of RZ 2012, RZ 2018 and the RZ 2012-2018 Change product are available in the Riparian Zones Nomenclature Guideline (Tamame et al. 2021), and RZ Product Specifications (Weissteiner et al., 2016). While the nomenclature document carries version information, it does not explicitly state that the changes refer to all three datasets. This should be stated prominently in the document, and the datasets should be given version numbers so that they can be matched to the correct documentation.

The product specification (short version), in turn, which was produced in 2015 refers only to the 2012 product, and there is no such documentation for further products (RZ 2018 and RZ 2012-2018 change products). This gap seems to be filled with the metadata information available at the CLMS webpage to some extent but seems less reliable providing a lower level of information control is assured for webpages. Another potential source of information is a validation report (Pennec & Lhernould 2020), which is provided in the technical library on the webpage. It is nevertheless unclear what is supposed to be the official product specification.

In particular, the information on the image source data used for classification of LC/LU classes is not clear. The RZ Nomenclature Guideline provides a list of all data sources without clearly distinguishing which product used which dataset. The webpage information must be used to clear the disambiguation

[1] For example, Riparian Zones 2012 product metadata described at https://land.copernicus.eu/local/riparian-zones/riparian-zones-2012?tab=metadata provides the following information: "In 2017, to allow for a harmonisation of the nomenclatures applied to the different local component products (Costal Zones and N2K), a revision of **the nomenclature was undertaken which resulted in a reduction of classes** (down to 56). A LC/LU dataset covering rivers pertaining to Strahler level 2 was produced applying the new nomenclature and the **previous dataset (covering Strahler levels 3 to 8) was re-coded to the new nomenclature**. The two datasets were merged together and a harmonised dataset covering rivers pertaining to Strahler levels 2 to 9 was produced. **In 2020 an additional exercise of harmonisation of the nomenclature (re-naming and re-coding) took place**. The current LC/LU layer differentiates 55 thematic LC/LU classes covering Strahler levels 2 to 9 for the reference year 2012." Accessed 22-06-2022.

or a deep knowledge about each of the datasets. It is suggested that information about primary and secondary data sources used for each of the datasets is clearly stated for each of the products.

The timeliness of reference data is 4 years, and no information is given on the data of acquisition of source data for a particular area or (best) spatial features (polygons). This is fundamental for checking the product accuracy since the lack of acquisition date prevents accurate selection of the reference data. In this report we have exemplified results from our attempted accuracy check but due to the above-mentioned deficiencies it was not possible to provide a reliable and systematic product verification. We suggest that each LC/LU class is attributed with monthly and yearly date of the source data from which the class was derived.

The search for source data specification from the data provider (Copernicus Space Component Data Store) is difficult since the search engine does not retrieve metadata based on the product codes (e.g. D2_MG2b_LOLA_011b gives no results, while it retrieves the descriptive name “Optical VHR2 coverage over EU 2011-2013”) while these codes are referenced in the RZ Nomenclature Guideline. In addition, the available metadata are not uniform among all the datasets while the webpage says it is going to be prepared according to the INSPIRE format. Especially older data is purely accompanied with metadata. It is recommended that the datasets referred to in technical documentations of CLMS are well referenced and a direct link is provided.

The RZ nomenclature guideline defines LC/LU classes to be identified, which limits the potential of the spectral identification capacity of the source datasets. For example, a spectral image of a grassland allows to identify different types of grasses and different types of grassland habitats. It results in delineation of neighbouring polygons with same class code, which seems unnecessary.

The delineation of class borders has not been updated in RZ 2018 products since RZ 2012 product. This results in incorrect classification of polygons especially if the LC/LU changed only in part of the polygon class.

6 Conclusion and recommendations

We have examined the potential of the Copernicus Riparian Zones dataset for monitoring the status and change of land cover/land use along waterways in Poland and Norway to support policies. After comparing the Riparian Zones dataset with national datasets, we conclude that the thematic accuracy was quite good at level 1 for Water, Cropland and Woodland and forest, but that other classes did not correspond so well with national data. Many of the discrepancies may be due to differences in the classification systems, source data and mapping instructions of the various datasets. These issues probably also affect the spatial resolution of the map product, which we found to be currently insufficient for detailed monitoring of land cover/land use along the edges of waterways. Nevertheless, the RZ products provide a standardized, harmonised methodology for the whole of Europe and provide a significant first step in enabling monitoring of land cover/land use in these dynamic and important areas.

During the work we uncovered several technical issues. We recommend that each dataset is given a version number and timestamp and that links to the matching technical documentation are made clearer. We also recommend that each feature of a RZ product is attributed with source data and date of acquisition. This is fundamental for reliable product verification based on national data and will extend the product usability for local uses.

7 Acknowledgments

This report was written as Deliverable 5.2 in the project InCoNaDa: "Enhancing the user uptake of land cover / land use information derived from the integration of Copernicus services and national databases".

The study was funded by Norway Grants 2014 - 2021 via the Polish National Center for Research and Development [grant no: NOR/POLNOR/InCoNaDa/0050/2019-00].

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NIBIO - Norwegian Institute of Bioeconomy Research was established 1st July 2015 as a merger between the Norwegian Institute for Agricultural and Environmental Research, the Norwegian Agricultural Economics Research Institute and Norwegian Forest and Landscape Institute.

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