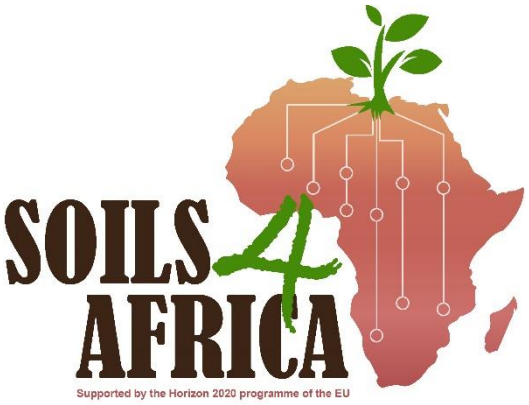

Annex to D4.1: Map of agricultural land of continental Africa

Project No. 869200

Version 1.0

28 September 2021

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Contents

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1. Background

On November 30, 2020, the report 'D4.1 Map of Agricultural Land of Continental Africa' with accompanying GIS layer of the map ('MAL_AFRICA1.tif') were submitted as deliverables of the Soils4Africa project. A first (qualitative) validation round in which the map of agricultural land (MAL) was compared with earth observation imagery showed that the map approximated the extent of agricultural land reasonably well but that there were also some shortcomings. Most important shortcoming was the underestimation of the extent of agricultural (grazing) land in the semi-arid areas. But also, in the more humid areas there were substantial areas that were clearly used for agricultural purposes when looking at earth observation imagery but were not classified as such. Because the MAL is a key input for the design of the Soils4Africa sampling scheme, we decided to revise the decision rules used to classify agricultural land from Copernicus satellite imagery to address these shortcomings. The updated rules were subsequently implemented to produce a second version of the MAL, as well as a map of agricultural land classes that distinguishes the different classes of agricultural land that are outputs of the decision rules. The map of agricultural land classes provides an additional stratification of the agricultural land area of Africa that will be used for inference and synthesis of data an information of soil quality.

This document is an annex to the Soils4Africa report 'D4.1: Map of Agricultural Land' that describes the classification methodology and the first version of the MAL in more detail.

2. Decision tree and rules for classification of agricultural land in Africa

The decision tree in Figure 1 below, specifies the rules to conclude on the category of agricultural land for each grid cell based on the Copernicus Global Land Cover (CGLC) data. There is a certain systematic in the classification system in which at the first level distinction is made based on the discrete land cover class in the CGLC, which is either Cropland, Herbaceous vegetation, Shrubland, or Forest. At the subsequent level distinction is made based on fractional land cover (FLC) class percentages. Again, for land cover classes that are relevant to indicating agricultural use. For the pixels classified as Cropland (CL) this further distinction is based on the fractional Herbaceous Vegetation (HV) and fractional Forest (Fo) cover. For the other classes the further differentiation is made in first instance on fractional cropland cover and in second instance on HV or Shrubland (SL), which are generally complementary at that level. Also, the agro-ecological zone (AEZ) is used as a criterion, even though the secondary landcover class is indicative of the AEZ. Forest or woody vegetation as secondary landcover class is indicative of the humid tropics / tropical rainforest zone, the shrubland is characteristic of the sub-humid zone (derived savanna and guinea savanna region), whereas the HV is characteristics of the semi-arid and arid regions (northern Guinea savanna, and Sudan savanna). The ultimate interpretation and validation of the land use classes the will be based on the observations on land use and land cover characteristics at the project's sampling point locations.

Rules and part of the decision tree classifying for Cropland

For the area classified as *Cropland* in the CGLC, a relatively high fractional HV cover is characteristic for the semi-arid and arid regions and indicates areas that are only partially used for dryland cropping, and for which grazing is the dominant land use. Field patterns need to be clearly visible, but may be more indicative of the homesteads rather than cropland per se. The fields are

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generally relatively large and do not have a homogeneous appearance. Agriculture is rainfed and land use less intensive.

The areas with relatively high fractional forest cover are indicative of the humid and sub-humid regions where woody vegetation is part of the land use systems. It may be associated with tea plantations for example in which case a high fractional HV cover is a result of the very smooth canopy characteristics of these plantations. Pixels classified as *Cropland* are observed in these plantations, but difficult to explain and these pixels are found in association with pixels classified as '41' by rule [8d]. Otherwise, areas with relatively high fractional forest cover are indicative of smallholder agricultural systems with a fragmented landscape in which we have woodlots, living fences, homesteads, etc., that explains the relatively high fractional forest cover. Currently, we are not able to distinguish between the smallholder systems and plantations with our decision rules, but these are easily recognised based on their spatial pattern Plantation crops, like tea plantations are mapped as part of the area classified as "forest" as major land cover class (see class 4.1), but this is not exclusive.

As a result, we have 4 classes of cropland

1.1 True cropland / arable land with intensive land use systems (generally high fraction cropland cover >45%.
1.2 Smallholder farmland, rainfed semi-intensive agriculture.
1.3 Plantation crops like tea plantation, other than tree plantations.
1.4 Dryland mixed arable and grazing land, low intensive agriculture.

For classification, 1.2 and 1.3 are combined in one class (13). These classes are classified from the Copernicus imagery with the set of rules below (where class 1.1 is coded with '11' in the map, etc.).

Rules for area classified as *Cropland*

[1] IF SLC class = "Cropland" AND FLC-HV < 25% THEN MAL= "11"

[8a] IF SLC class = "Cropland" AND FLC-HV ≥ 25% AND FLC-Fo < 23% THEN MAL = "14"

[8c] IF SLC class = "Cropland" AND FLV-HV ≥ 25% AND FLC-Fo ≥ 23% (but < 50%) THEN MAL = "13"

Rules and part of the decision tree for areas classified as Forest

For areas that are classified *Forest* (either 'Open forest' or 'Closed forest') in the CGLC, a further distinction is made based on fractional cropland (CL) cover. A fractional CL cover of ≥15% already indicates that the area is used for cropping. If we have in addition a relatively high HV fractional cover this is indicative of a plantation crop with a smooth canopy surface (like tea plantations), meaning that in class 1.3 we have errors of commission: areas wrongfully classified as "plantation".

If the fractional CL cover is <15%, it is generally very low (often 0%). But we did not introduce a separate criterion because of omissions in the classification. Further distinction is made based on the fractional HV cover. A relatively high fractional HV cover percentage indicates areas of agricultural colonisation that are actively being deforested characterised by larger open spots

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within the forest area, up to areas where little of the forest remains. It covers large areas in DRC for example. As a consequence, the FLC-SL is reduced (at least less than 40%).

In those 'forest' areas where shrubland dominates we find largely completely deforested areas with secondary regrowth of woody vegetation with a single vegetation structural layer, in some case very dense bushland. Old tree plantations like teak plantation in Nigeria, often more than 60 – 70 years old fall under this category but cannot be distinguished as a separate class. These do have a very distinct spatial pattern and could be recognised as such, but rather difficult to capture in rules for automated classification. These are not forested areas, these lands may be used for agricultural purpose, but the land use intensity is very low.

As a result, we have 4 classes of agricultural land including classes for deforested area and tree plantations and agricultural colonisation area.

4.1 Plantations of woody plants, like tea plantations, with a smooth canopy structure often associated with woodlots, shade trees or other.
4.2 Mixed farmland typical of the derived savannah AEZ with various arable (e.g., maize, cassava) and tree crops, woodlots, bush fields and land lying idle.
2.1 Deforested land with secondary regrowth, dense bushland including (old) tree plantations, like old and abandoned teak plantations, including oil palms and other.
2.2 Agricultural frontier area, with open woody vegetation mainly used for grazing and little cropland – subsistence agriculture.

Rules for area classified as *Forest* ("Closed forest" OR "Open forest")

[4]. IF SLC class = "Forest" AND FCL-CL ≥ 15% AND FLC-HV < 25% THEN MAL="42"

[8d]. IF SLC class = "Forest" AND FLC-CL ≥ 15% AND FLC-HV ≥ 25% (but < 50%) THEN MAL = "41"

[8b]. IF SLC class = "Forest" AND FLC-CL < 15% AND FLC-SL < 30% AND FLC-HV ≥ 25% (but < 50%) THEN MAL = "22"

[3]. IF SLC class = "Forest" AND FCL-FO ≥ 30% AND FLC-CL < 15% AND FLC-SL ≥ 30% THEN MAL = "21"

Rules 8b and 3 are included to distinguish between Forest classes in which either Shrubland or Herbaceous Vegetation is the second dominant land cover class. Both are deforested areas (not forest areas) but dominated by woody vegetation in the one (tree plantations, secondary woody vegetation) and herbaceous vegetation in the other (grassland).

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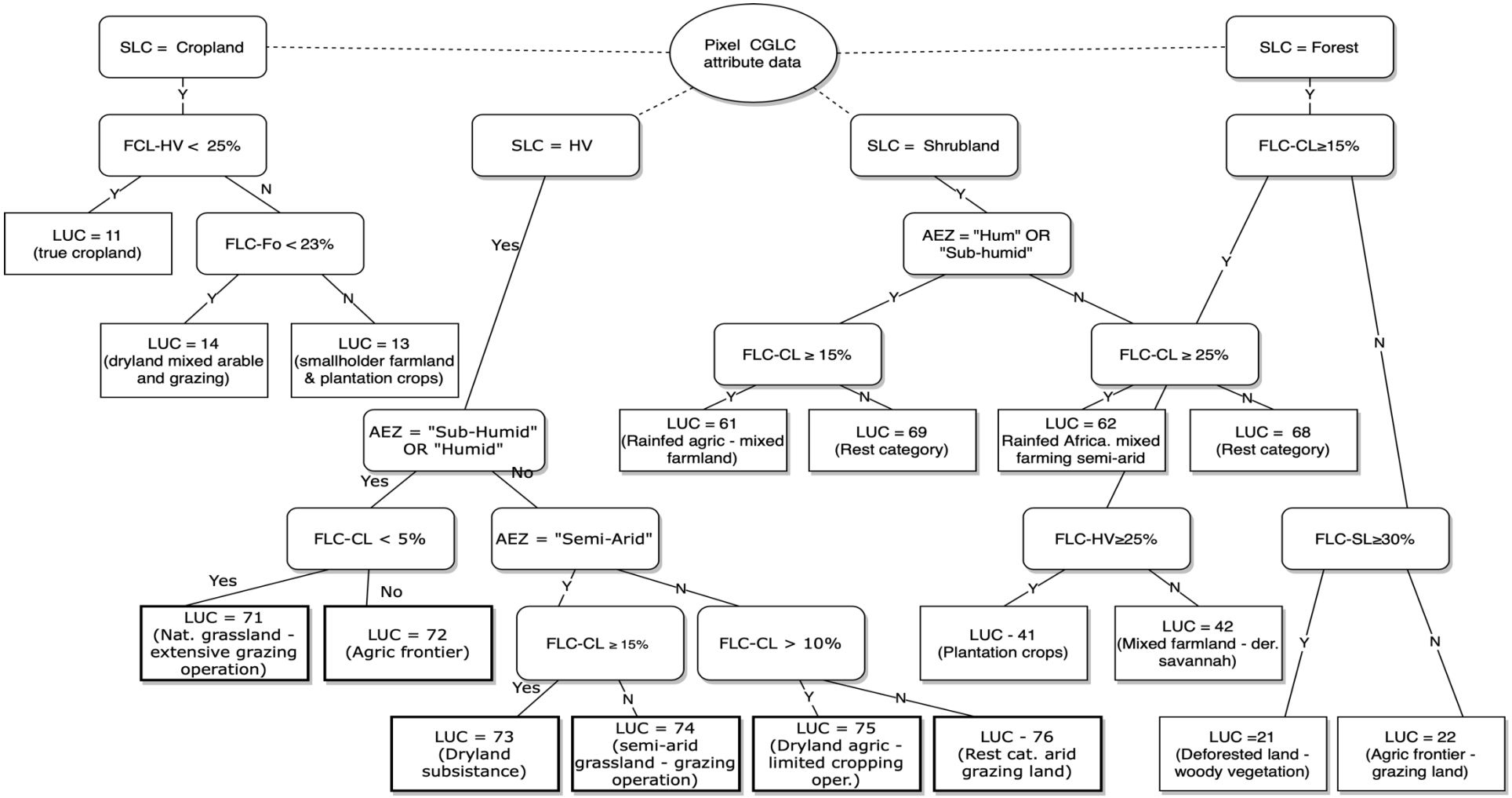

Figure 1 Decision tree for classification of agricultural land based on CGLC data.

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Rules and part of the decision tree for areas classified as Shrubland

For areas classified as *Shrubland* in the CGLC, further distinction is made based on fractional crop land cover. Further differentiation based on fractional forest cover did not seem to be needed as this is covered under the area classified as Forest. If fractional CL cover is larger or equal to 25%, we classify the area as agricultural land and mixed farmland. Fields patterns are clearly observed, but fields do not constitute a contiguous pattern and shape of the fields are irregular and fields often are not homogenous. Land is used for cropping mainly and grazing of those parts of the land being fallowed and lying idle. Where cropland is concentrated it is recognised as cropland. If fractional CL is less than 25% it is not classified as agricultural land, though it will be used for grazing (rather extensive). This land use is typical for the savanna areas of the southern and northern guinea savanna of West Africa and cropland (continuous and intensive) is generally recognised as such.

There is only one class of agricultural land in this category, but distinction is made between agro-ecological zones:

6.1 Rainfed agriculture, mixed farmland with cropland and grazing land, discontinuous irregular field pattern. Semi-commercial farming intermediate intensification level (sub-humid and humid regions).
6.2 Rainfed agriculture, mixed farmland with cropland and grazing land, discontinuous irregular field pattern. Semi-commercial farming intermediate intensification level (semi-arid and arid regions).

Rules for area classified as *Shrubland*:

[6a] IF SLC class = “Shrubland” AND AEZ = Sub-humid or humid AND FCL-CL ≥ 15% THEN MAL = “61”

[6b] IF SLC class = “Shrubland” AND AEZ = Semi-arid or arid AND FCL-CL ≥ 25% THEN MAL = “62”

Rules and part of the decision tree for areas classified as Herbaceous Vegetation

For areas classified as *Herbaceous Vegetation* in the CGLC, further distinction is based on fractional cropland cover as well. We find these areas of herbaceous vegetation mainly in the semi-arid and arid region. Areas that are used for annual crops stand out and are generally clearly recognised as *Cropland* in the CGLC layer. Therefore, with a fractional cropland cover between 15% to 50%, this indicates areas that are indeed partially cropped or being very extensively cultivated. This does represent dryland agriculture and subsistence farming systems. Fields/parcels are generally clearly recognised but do not necessarily indicate the area being cropped. Land use intensity is very low. The area may be used for grazing, but it will be very extensive use of the land. This category is closely associated with class 1.4

Areas classified as *Herbaceous Vegetation* in the sub-humid zone or even humid zone, do represent natural grassland that are being used for grazing. We find extensive areas in the South Sudan republic classified as such in which no arable land is found, and fractional cropland cover is zero or almost zero. However, we find larger deforested areas the semi-humid AEZ of DRC for

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example that are classified as *Herbaceous Vegetation* as well. These are not 'natural' grasslands, and we find relatively high fractional cover of cropland. Not many pixels are classified as *Cropland*, probably because these are not continuously used. Cropping intensity will be rather low, with a lot of idle land. A field pattern will also have been established clearly. In this AEZ we probably would have expected much higher percentage of shrubland, like we find in the derived savanna and southern guinea savannah of western Africa, but this is probably because of the more recent history of land clearing and probably the dynamic nature of land use and land cover change.

The original decision rules for the area classified as *Herbaceous Vegetation* in the CGLC have been updated to reflect this situation, but also to clear some discrepancy between the original decision rules. Consequently, we found large areas in DRC not classified as agricultural land while clear field patterns are present. The pattern is consistent with larger parts that seemingly seem to have been deforested quite some time ago and where agriculture has been established, though the field pattern is non-consecutive with clustered and dispersed fields and probably not well established.

There are 5 classes of agricultural land in this category

7.1 Natural grasslands use for extensive grazing operations (sub-humid and humid regions).
7.2 Agricultural frontier area with larger deforested parts with low-intensity agriculture – grazing and cropping operations (sub-humid and humid regions).
7.3 Dryland subsistence agriculture, partial cropping and grazing area (semi-arid region).
7.4 Dryland grazing area, low intensity (semi-arid region).
7.5 Dryland subsistence agriculture, partial cropping and grazing area (arid region).

Rules for area classified as *Herbaceous Vegetation*:

[7a] IF SLC class = "Herbaceous Vegetation" AND AEZ = "Sub-humid or Humid" AND FLC-CL < 5% (AND FLC-HV ≥ 25%) THEN MAL = "71"

[7b] IF SLC class = "Herbaceous Vegetation" AND AEZ = "Sub-humid or "Humid") AND FLC-CL ≥ 5% THEN MAL = "72"

[7c] IF SLC class = "Herbaceous Vegetation" AND AEZ = "Semi-arid" AND FLC-CL ≥ 15% THEN MAL = "73"

[7d] IF SLC class = "Herbaceous Vegetation" AND AEZ = "Semi-arid" AND FLC-CL < 15% THEN MAL = "74"

[7e] IF SLC class = "Herbaceous Vegetation" AND AEZ = "Arid" AND FLC-CL > 10% THEN MAL = "75"

There will be one rest category and that is for 'arid' with a fractional cropland cover of less or equal to 10%. These will be the very extensively grazed grasslands, that we did not map here (since this area is outside the scope of soil sampling for the project), but could be identified as a separate class *'wild' grazing area* (class 76 in Figure 1).

3. Results

The new classification rules were applied to the CGLC imagery and a new agricultural land mask was produced at 100 m resolution (Figure 1).

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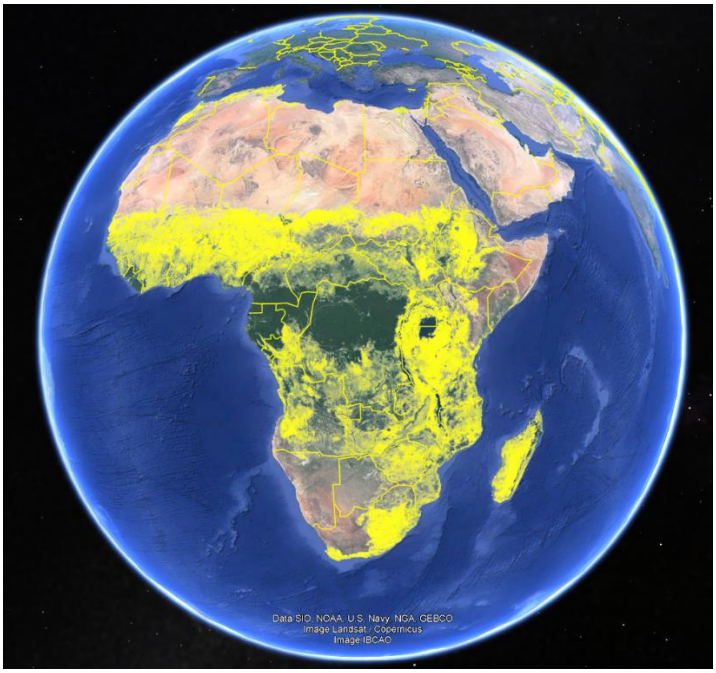

Figure 2. Map of Agricultural Land version 2.

The MAL v2 classifies 8.8M ha of land as 'agricultural' (~29% of the continent), in the first version this was 7.9M. Figure 3 shows an overlay of the two maps and illustrates that the area of agricultural land got primarily extended in the semi-arid regions and includes now important agricultural land in the Republic of South Africa as well. Figure 4 shows the agricultural land classes and a map detail in Figure 5.

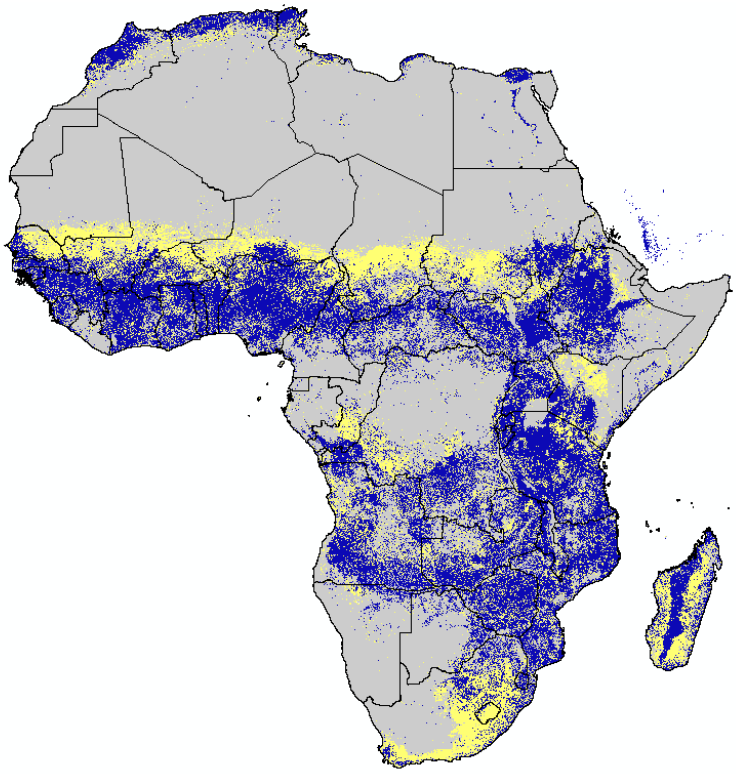

Figure 3. Overlay between MAL version 2 (yellow) and MAL version 1 (blue) showing the larger extent of the area of agricultural land for version 2. The grey area indicates 'non-agricultural land'.

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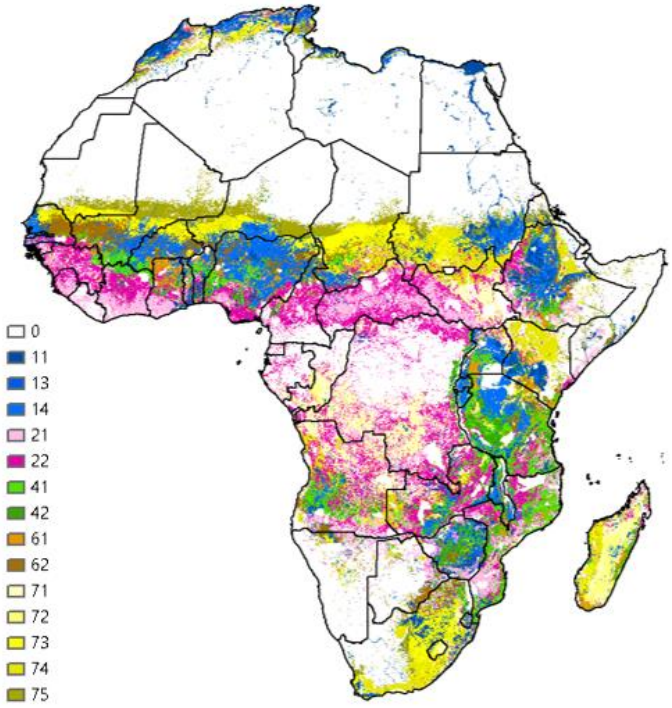

Figure 4. Map showing 14 agricultural land classes as classified by the decision rules of this report.

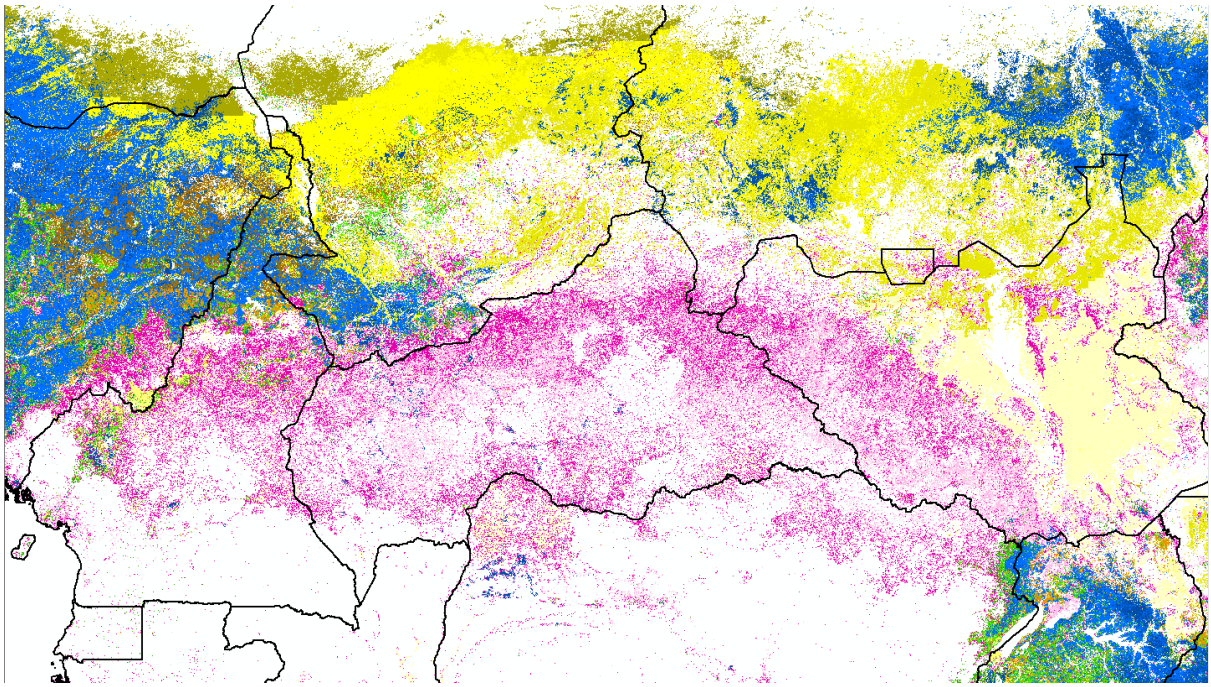

Figure 5. Detail of the map with agricultural land classes, for central Africa showing Cameroun, CAR, South Sudan and part of Sudan Chad and Nigeria.

Figures 6- shows some examples of improved classification of agricultural land in the second version of the MAL compared to the first version.

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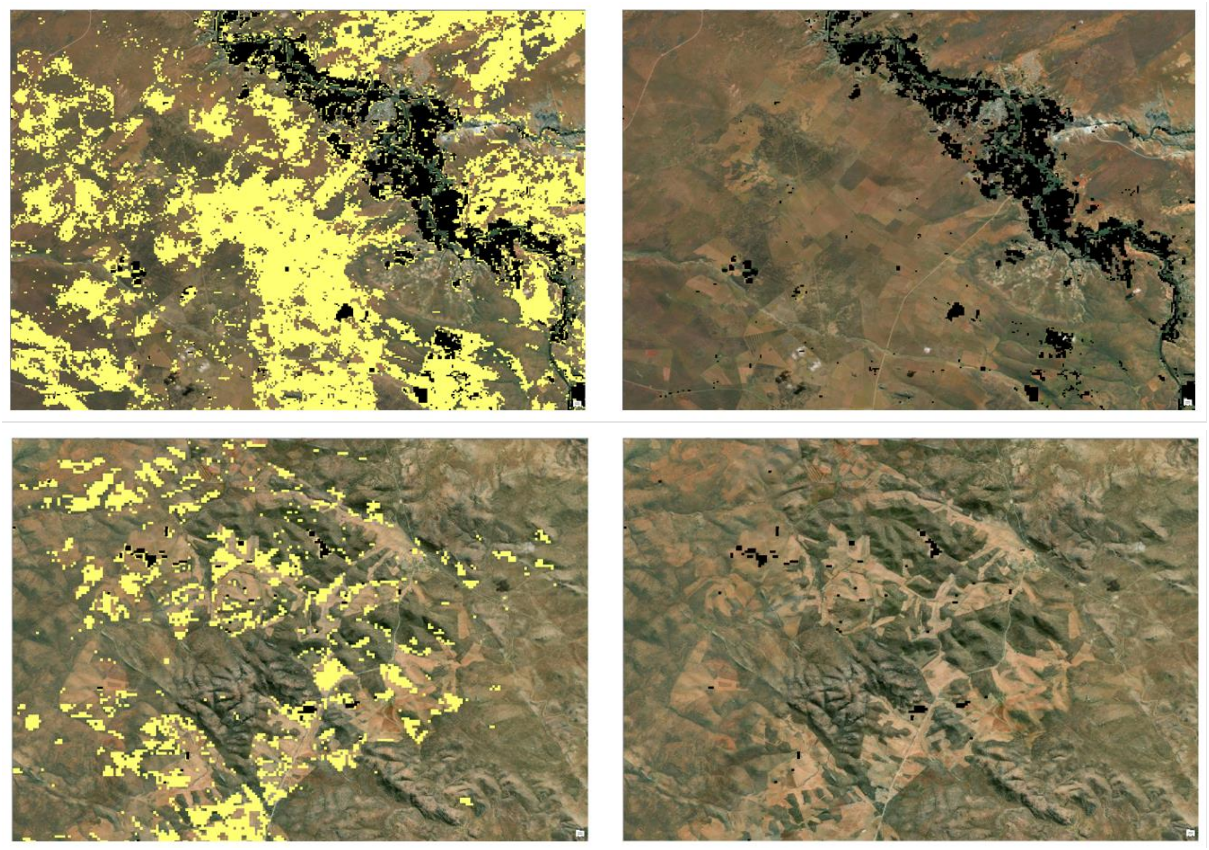

Figure 6. Example of the classification of agricultural land for the second (left; yellow) and first version (right; black) of the MAL for two areas in South Africa.

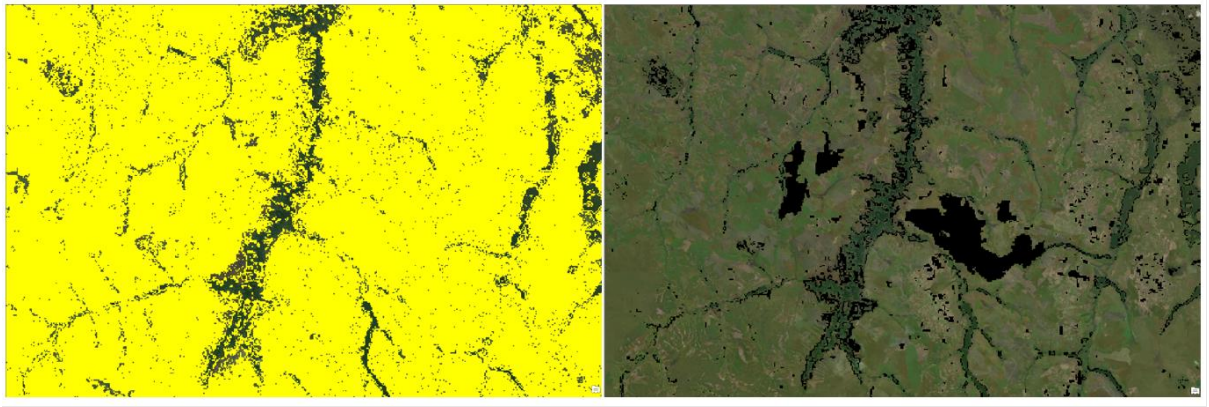

Figure 7. Example of the classification of agricultural for the second (left; yellow) and first version (right; black) of the MAL for an area in DRC.

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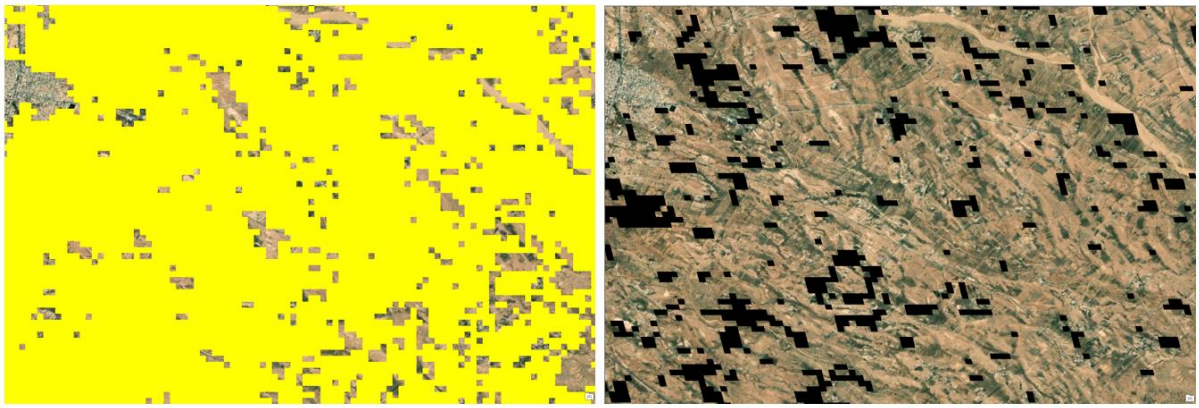

Figure 8. Example of the classification of agricultural for the second (left; yellow) and first version (right; black) of the MAL for an area in Tunisia.

4. GIS files

The second version of the MAL, as well as the MAL classes map, are delivered in GeoTiff format. The layers are available in WGS84 lat-lon (epsg:4326) projection (0.00099 deg. resolution).

File names:

MAL_AFRICA2.tif: agricultural land mask, version 2 (based on rules described in this report).

MAL_AFRICA2_classes.tif: agricultural land classes (based on rules described in this report).

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