Description of Knowledge-based expert system: Knowledge base production rules and inference engine mechanisms.

The knowledge base was built using spectral, temporal and spatial constraints to identify the main agricultural systems and natural vegetation types in the study area. The production rules in the knowledge base were established based on a training dataset of 1,750 points of known land use types randomly searched using visual interpretation of a combination of Landsat and very high-resolution imagery (Google Earth) for the period of study. The thresholds for each land use class were calculated from the statistical distribution of pixel values in the training dataset. The production rules are described below:

Natural vegetation: Production rules to identify natural vegetation evaluated images from the February to May temporal window. The February to May temporal window covers the peak of the dry season and NDVI values are low throughout the region. Pixels with NDVI value higher than 0.25 are considered as potential natural vegetation pixels. The dataset of the training dataset showed that only natural vegetation surfaces presented some vegetative activity during the temporal window and had NDVI values higher that the threshold.

- Pixels were classified as stable natural vegetation if more than 60% of its valid observations met the production rule (the majority of the images during the temporal window had NDVI values that indicated vegetative activity).
- Pixels were classified as non-stable natural vegetation if between 20% than 60% of its valid observations met the production rule. Natural vegetation with lower densities or undergoing land cover change processes would result in less images meeting the NDVI threshold more sparsely.

Burned area: Production rules to identify burned areas evaluated images from the July to October temporal window. This temporal window corresponds to the 'fire season' in which agricultural fields are prepared before the onset of the first rains. Pixels with TOA short wave infra-red values lower than 0.2 were considered as burned. A pixel was labeled as burned if at least one observation met the production rule during the 2014 – 2016 period.

- Natural vegetation pixels meeting the burned area production rule were labeled as non-stable natural vegetation. Fire is a common management tool in Sub-Saharan Africa (Ichoku et al., 2016). Fire is often use to clear the land from natural vegetation as part of a gradual agricultural expansion process. The burning of an area during the acquisition window period was assumed as an indication of land transformation.

Rain-fed agriculture: Production rules to identify rain-fed agriculture evaluated images from the July to October temporal window. If the number of valid observations during this temporal window was lower than 5 (n=5), a NDVI maximum value composite was built with July to October images from 2014 to 2016. Pixels with NDVI value higher than 0.3 and not previously mapped as natural vegetation, were considered as potential rain-fed agriculture pixels. The dataset of the training dataset showed that this NDVI threshold captured agricultural surfaces even with plant densities or at earlier stages of the crop vegetative cycle.

- If a NDVI maximum value composite was used, pixels with NDVI value higher than 0.3 and not previously mapped as natural vegetation, were considered as rain-fed agriculture. If more than 5 cloud free observations were available, pixels were classified as rain-fed agriculture if more than 20% of its valid observations met the production rule.

Bare soil: Production rules to identify bare soil evaluate images from the July to October temporal window. This temporal window covers the rainy season. Pixels without vegetation during the rainy season were assumed to be bare soil. If the number of valid observations in lower than 5 (n=5), a NDVI maximum value composite is built with July to October images from 2014 to 2016. Pixels with NDVI value lower than 0.3 are considered as potential bare soil pixels.

- If a NDVI maximum value composite was used, pixels with NDVI value lower than 0.3 were considered as bare soil. If the number of valid observations in lower than 5 (n=5), pixels are classified as bare soil if more less than 20% of its valid observations met the production rule.

Water bodies and rivers: Production rules to identify water bodies and rivers evaluated images from the January to December temporal window (full year). Pixels with NDVI value lower than 0 were considered as potential water pixels.

- Pixels were classified as water bodies and rivers if at least one of its valid observations met the production rule.

Irrigation agriculture: Production rules to identify irrigation agriculture evaluated images from the January to April temporal window. This temporal window captures the typical irrigation agriculture pattern in the region. Pixels with NDVI value higher than 0.4 during this temporal window were considered as potential irrigation agriculture pixels. This NDVI threshold identifies vegetation activity of higher intensity than that of natural vegetation during the dry season.

- Floodplains were defined as areas of flat lands (slope < 2%) within 1.5 km of water bodies or rivers. Flat lands were identified from the Shuttle Radar Topographic Mission 30 m resolution digital elevation model (Farr et al., 2007). Pixels were classified as irrigation agriculture if more than 40% of its valid observations met the production rule and were located in floodplains. Pixels previously labeled as potential natural vegetation that met the abovementioned criteria were classified as irrigation agriculture. Pixels previously labeled as potential rain-fed agriculture that met the abovementioned criteria were also classified as irrigation agriculture.

Urban: urban pixels were not directly measured in the KBES. Urban pixels were extracted from the Global Human Built-up and Settlement Extent (HBASE) Dataset from Landsat product (Wang et al., 2017).

References:

Ichoku, C.; Ellison, L.T.; Willmot, K.E.; Matsui, T.; Amin, K.D.; Charles, K.G.; Jun, W.; 463 Eric, M.W.; Jejung, L.; Jimmy, A.; et al. Biomass burning, land-cover change, and the 464 hydrological cycle in Northern sub-Saharan Africa. Environ. Res. Lett. (**2016**), 11, 465 095005.

Farr, T.G., Rosen, P.A., Caro, E., Crippen, R., Duren, R., Hensley, S., Kobrick, M., 447 Paller, M., Rodriguez, E., Roth, L., Seal, D., Shaffer, S., Shimada, J., Umland, J., Werner, 448 M., Oskin, M., Burbank, D., and Alsdorf, D.E. The shuttle radar topography mission: 449 Reviews of Geophysics (**2007)**, v. 45, no. 2, RG2004, 450 at http://dx.doi.org/10.1029/2005RG000183.