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Contribution of GIS and participatory Mapping for the analysis of the cropping system in the circle of Kita, in Mali

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***Abstract*— *The development of geospatial technologies allows the creation of numerous services in all areas. In agriculture, their use is much more oriented towards mapping and evaluating agricultural areas. However, the identification and mapping of crops through GIS tools remains a major challenge especially in its African context. The objective of this work is to analyze the crop systems of the terroirs of Banfara, Madina Malinké and in the circle of Kita using GIS tools. To achieve this objective, we used the Google Earth Pro database for the years 2020 and 2021. Through a participatory approach, all the plots and the type of cultivation practiced were identified and mapped. After digitizing the agricultural plots, we carried out field observation in order to validate them. Geoprocessing operations and descriptive analyzes were then carried out. The methodological approach adopted allowed the exhaustive mapping of agricultural plots in the areas of Banfara, Madina Malinké and Toufinko. During the two agricultural seasons 2019-2020 and 2020-2021, the results show a dominance of cereal crops in the village of Banfara and a dominance of cash crops in the villages of Madina Malinké and Toufinko.*

I. INTRODUCTION

The diversity of crops in the landscape contributes to the reduction of weeds on the plots while allowing the improvement of yields (Ouyang et al., 2020). Additionally, a landscape with diverse plant species reflects nutritional diversity and food security (Kpienbaareh et al., 2020). Thus, mapping agricultural landscapes for the identification of crop types, assessing their spatial distribution and cropping systems is essential to guide decision-making in agricultural planning and environmental management (Kpienbaareh et al., 2021). However, mapping crop types in smallholder farming systems in sub-Saharan Africa remains a challenge due to the cost of data, homogeneous landscape characteristics, climatic conditions limiting the clarity of images during much of the year.

In fact, satellite images available to the general public are limited for these types of operations. According to (Bellon De La Cruz, 2018) in West African countries, the only possibility offered by these satellite images is the evaluation of the area of agricultural masks. Moreover, satellite images acquired in Africa are most often difficult to use due to cloud cover at the time of acquisition of these images (Chen et al., 2018; Pittman et al., 2010; Wei et al., 2020).

The Google Earth software has a freely accessible image database (in RGB color) which is regularly updated. In recent years, many researchers have used data from this software as part of their studies (Baro et al., 2014; San Emeterio & Mering, 2021). Although these authors used the background of Google Earth software for different studies such as urban planning, it also offers great exploitable potential in agriculture.

Participatory mapping is an old practice allowing a finer representation of a territory with local stakeholders. Indeed, this participatory mapping method is generally limited to the representation of urban practices or the simple location of geographical entities on a map, from the mapping of territorial changes to the distribution of socio-community infrastructures (Cormier - Salem et al., 2017; Lefebvre et al., 2017; Choplin & Lozivit, 2019). In agriculture, it is essential to co-construct the agricultural land in the presence of local producers in order to highlight the choice of crops on the plots and their sequences over different agricultural seasons (Traoré & Le Bars, 2018).

In this article, we adopted a combined approach of participatory mapping with geospatial technologies to map the sequence of crops in the circle of Kita in Mali in order to obtain an accurate representation of the agricultural landscape of the terroirs concerned.

II. METHODOLOGY

2.1 Geographical framework

This work was carried out in three areas (Banfara, Madina Malinké and Toufinko) located in western Mali, in the Kita circle (**Fig.*1***). Agriculture is the main activity of the inhabitants of these three regions.

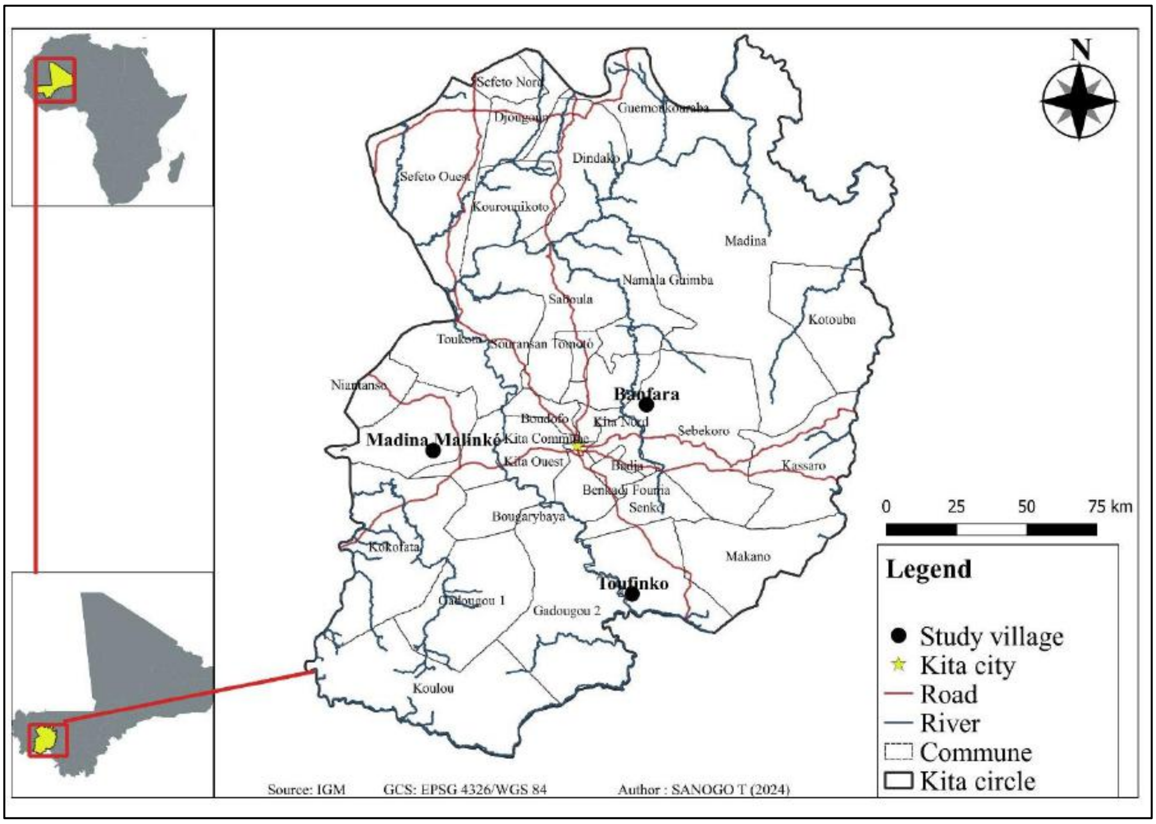

Fig.1: Location of study sites

The Banfara village land is a locality attached to the rural commune of Sebekoro to the east of the urban commune of Kita. It is between the geographical coordinates 9°14'0" and 9°18'0" of western longitudes and 13°9'20" and 13°11'10" of northern latitudes with an area of 29 Sq.km. Madina Malinké is a village located in the commune of Kobri in the West and 45 km from the town of Kita. Its geographical area is located between longitudes 9°56'0"W and 9°58'0"W and latitudes 13°0'00'N and 13°03'0"N with an area of 22 Sq.km.

The village lands of Banfara and Madina Malinké all have similar physical characteristics. They are located in the Sudanian climatic zone with an average annual rainfall which varies between 600mm and 1200mm of rain per year. The temperature varies between 25°C and 33°C. The relief is relatively flat, leaving room for very large shallows. The type of soil most encountered in the terroirs is loamy. The vegetation is made up of a carpet of shrub savannah which dominates but also a carpet of tree savannah located in the southern part of the Banfara region. In the Madina Malinké land, the shrub savannah also constitutes the large plant cover, but we also observe a gallery forest which spreads out along the watercourse.

The Banfara region has a population of 786 inhabitants. According to the general census of the population of the habitat, the region of Madina Malinké was home to 852 inhabitants (INSTAT-MALI, 2009).

The Toufinko region is a hamlet of Sirakoro (the capital of the rural commune of Sirakoro) on the Bakoye River. It is located south of the town of Kita over a distance of 70km. With an area of 27 Sq.km, it is between longitudes 9°17'30"W and 9°20'0"W and latitudes 12°30'00"N and 12°34'0"N. The average annual rainfall varies between 700mm and 1300mm of rain per year (IER, 1976). Its population is 378 inhabitants (PDSEC, 2021).

2.2 Materials

The equipment used for this research is essentially geomatics software, including Google Earth and Qgis for geoprocessing and data analysis. Then, a questionnaire (guide) was developed and sent to farm managers to identify the types of crops on the plots delimited by agricultural campaign.

2.3 Methods

Data collection was done in two phases simultaneously. First, the Google Earth image is projected on a screen which allows the identification of the different space objects. Then, using landmarks or orientation points (roads, rivers, mosques, etc.) visible in the image, each farm manager follows the path that leads to his or her field. After identifying the cultivated area, discussions were held to delimit the different plots. This delimitation is assisted by other producers to avoid any confusion. The boundaries of the plots are thus materialized in the Google Earth software. Secondly, the sequence of crops practiced on each identified plot is then administered in a questionnaire using the administration of the questionnaire incorporated in a tablet. The main informations on the plots are: the identification number of the plot which is similar to the identification code on Google Earth, the first and last name of the farm manager, the type of crops on the plot during 2019-2020 the agricultural campaign and that of 2020-2021.

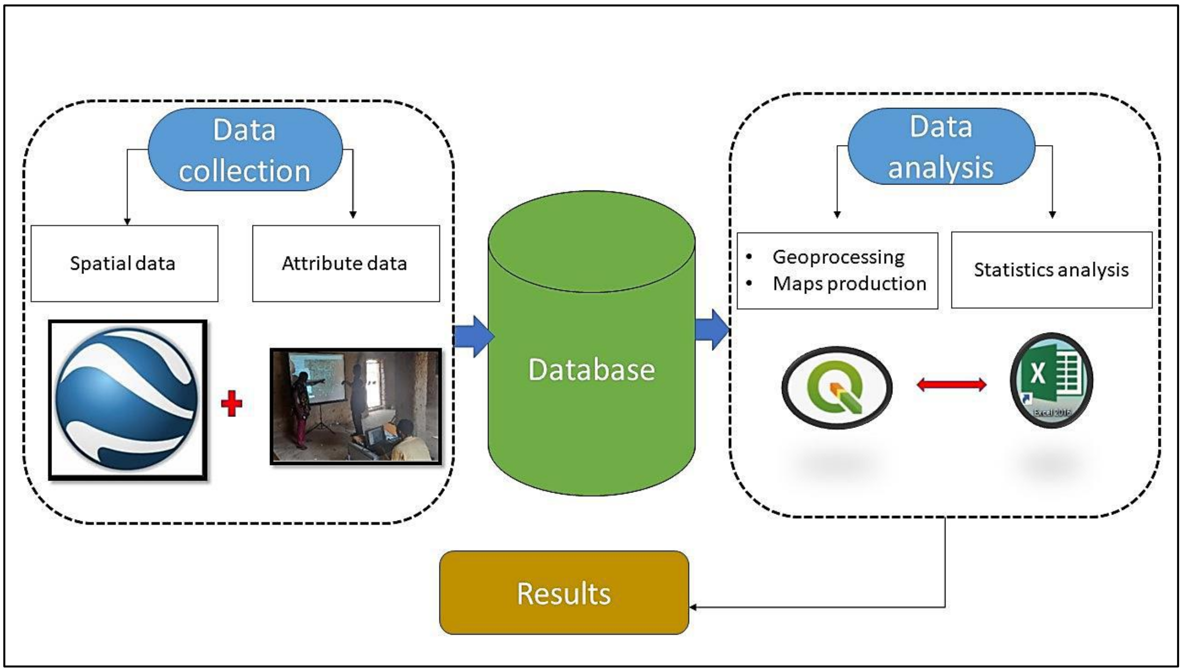

Fig.2 : Methodological diagram of culture mapping

We carried out geoprocessing of the digitized data on Google Earth (GE) and the questionnaires. This phase essentially consisted of making it easier to manipulate the data digitized on Google Earth in Keybole Markup Language (KML) format and creating a link between the tabular data (plot identification code, first name and last name of the head of farm, type of crops) and geographical data. To do this, the digitized polygons (plots) were converted from KML format to “Shapefile” format. To link geographic and tabular data, the attribute table management operation (attribute join) was carried out in QGIS under the ***“ join ” function.*** Despite the high precision of the images from the Google Earth software and the great ability of farm managers to read the image, the cartography was validated by comparing the results obtained with the realities on the ground. To do this, in each terroir, ten (10) plots were selected by reasoned choice in order to carry out validation. The centroid points of these parcels were then created and integrated into a mobile GIS application (QField). A close correspondence between the mapped plots and the realities on the ground was therefore noted. Additional analyzes using the descriptive statistics method were carried out to obtain statistical information. This is the area per type of crop in hectare and percentage.

III. RESULTS

3.1 Mapping of Banfara crop rotations during the 2019-2020 and 2020-2021 agricultural seasons

During the 2019-2020 agricultural campaign, the crop rotation map shows an uneven distribution of species cultivated on the different plots (**Fig.3**).

The results show a high concentration of crops in the center of the terroir. They indicate that the plots cultivated with cotton during the 2019-2020 agricultural campaign are highly concentrated in the South-East of the region. Food crop plots (corn, millet, sorghum and rice) are mainly located in the center. The peanut plots are distributed on both sides. The size of the plots varies greatly. Despite an aggregation of food crops (corn, millet, sorghum and rice), cotton soles have a very large influence on cultivated areas.

Cotton plots represent 34% of the total cultivated area, cereal crops 30%, peanut plots constitute 20%, sesame, market gardening and fallow represent respectively 7%, 4% and 5%.

During the 2020-2021 agricultural season, the distribution of crops underwent changes (**Fig.*4***). The cultivated area in the South of the region is mainly characterized by the dominance of cotton plots but they are also much more representative in the North-West than all other speculations. As for the plots of food crops, peanuts and sesame, they are scattered throughout the land. The plots of market gardening are located all around the home site.

During this agricultural campaign, the results show that the area allocated to cotton cultivation increased. While it occupied 34% of the total crop area during the 2019-2020 agricultural season, the cotton area amounts to 42%.

This increase in the area of cotton cultivation came at the expense of food crops which increased from 30% during the previous campaign to 25% during the 2020-2021 agricultural campaign. Peanut plots represent 19%, sesame cultivation, market garden products and fallow land make up a total of 14%.

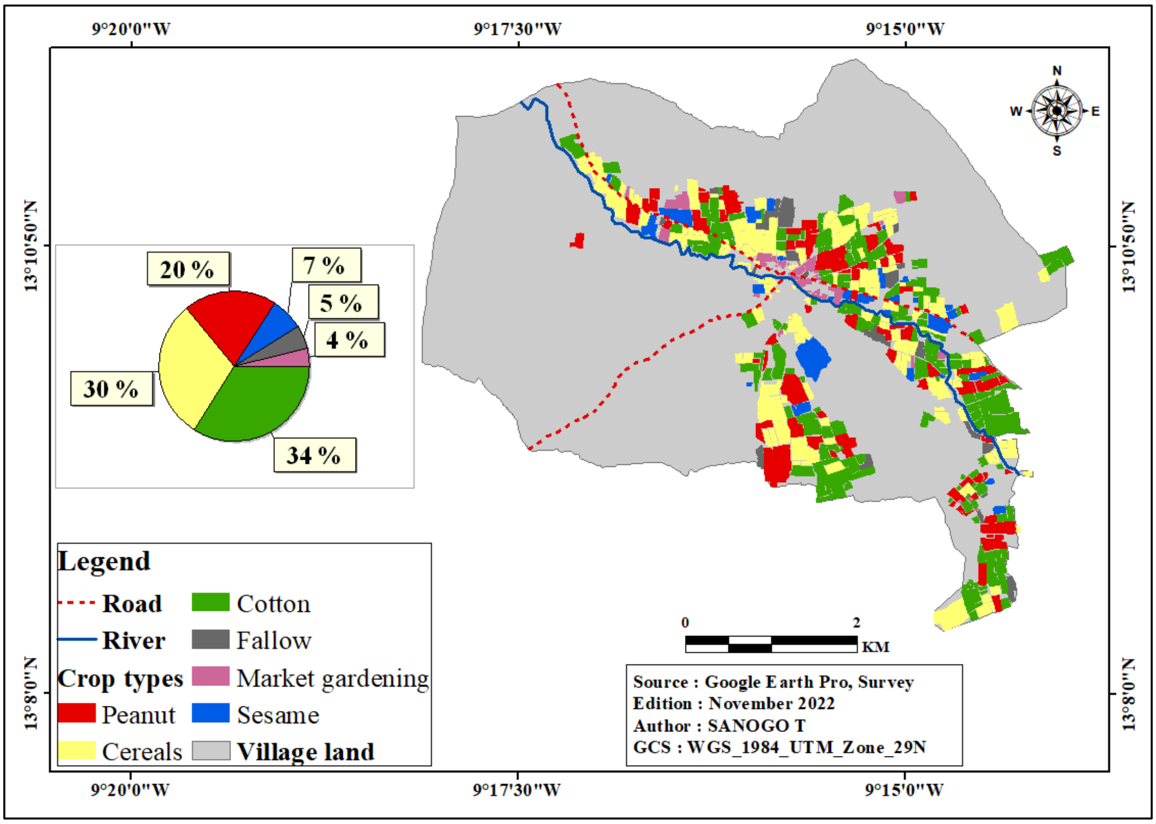

Fig.3: Distribution of Banfara crops during the 2019-2020 agricultural season

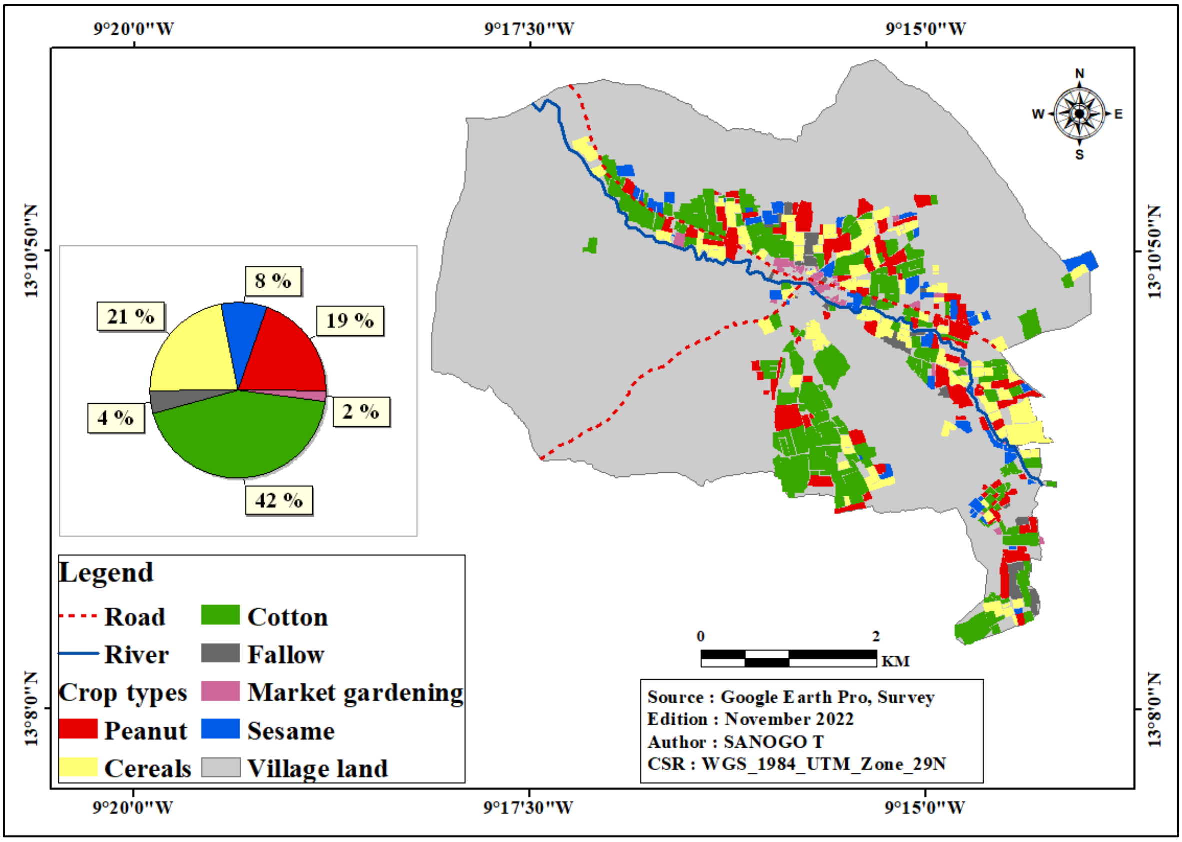

Fig.4: Distribution of Banfara crops during the 2020-2021 agricultural season

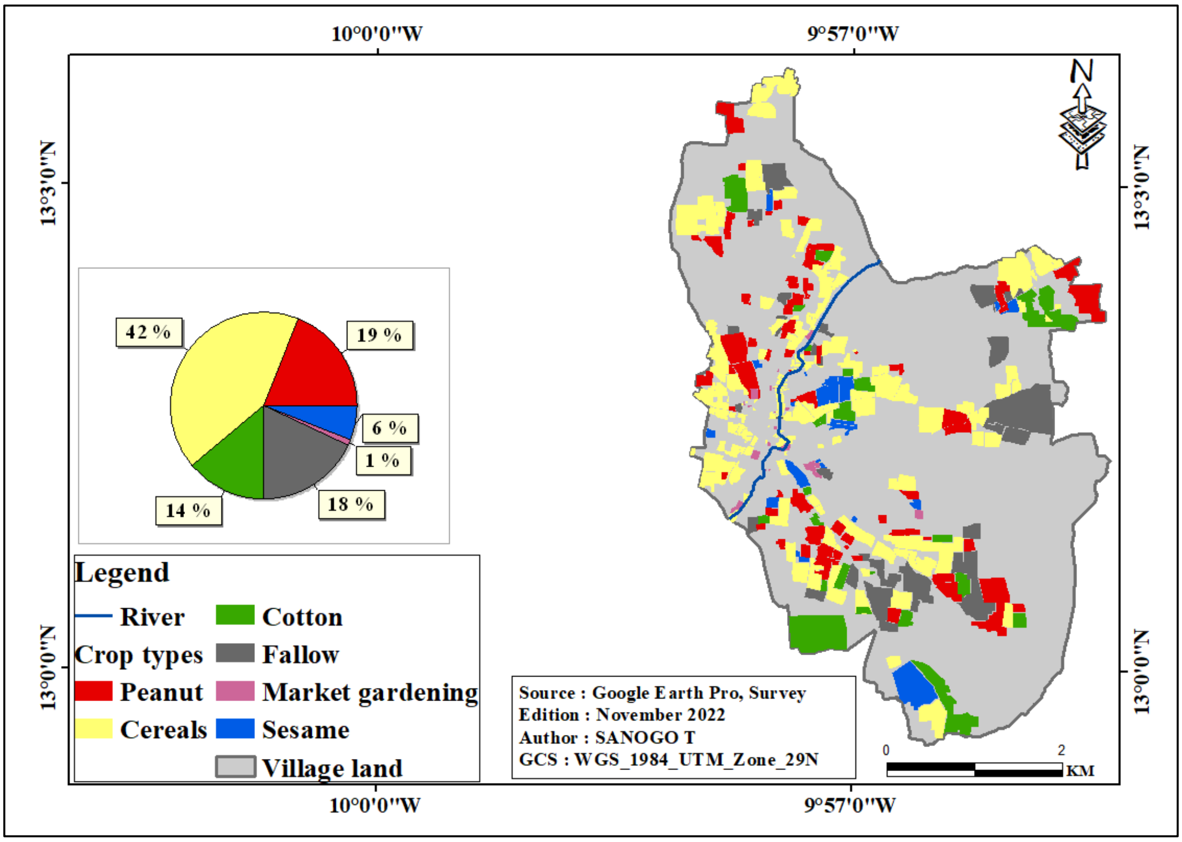

Fig.5: Distribution of Madina Malinké crops during the 2019-2020 agricultural season

3.1 Mapping of Madina Malinké crop rotations during the 2019-2020 and 2020-2021 agricultural seasons

The distribution of crops in the Madina region is marked by a strong dominance of food crop plots (**Fig.*5***).

In the North and West, the cereal and peanut plots are the most representative, in the South, we observe emulation between the cereal, peanut and cotton plots but also some fallow plots. In the South, cereal plots dominate with the presence of a few cotton and peanut plots and fallow plots.

In Madina Malinké during the 2019-2020 agricultural campaign, cereal crops occupied 42% of the total cultivated area, peanuts represented the second dominant crop with 19%, fallow and cotton had 18% and 14% respectively. Plots with sesame and vegetable crops were the lowest represented with 4% and 1%.

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During the 2020-2021 agricultural campaign, the distribution of crops is characterized by a different trend from the past campaign (**Fig.*6***). In the North, peanut cultivation dominates and fallow plots, cotton cultivation are highly concentrated in the South with a few cereal and peanut plots.

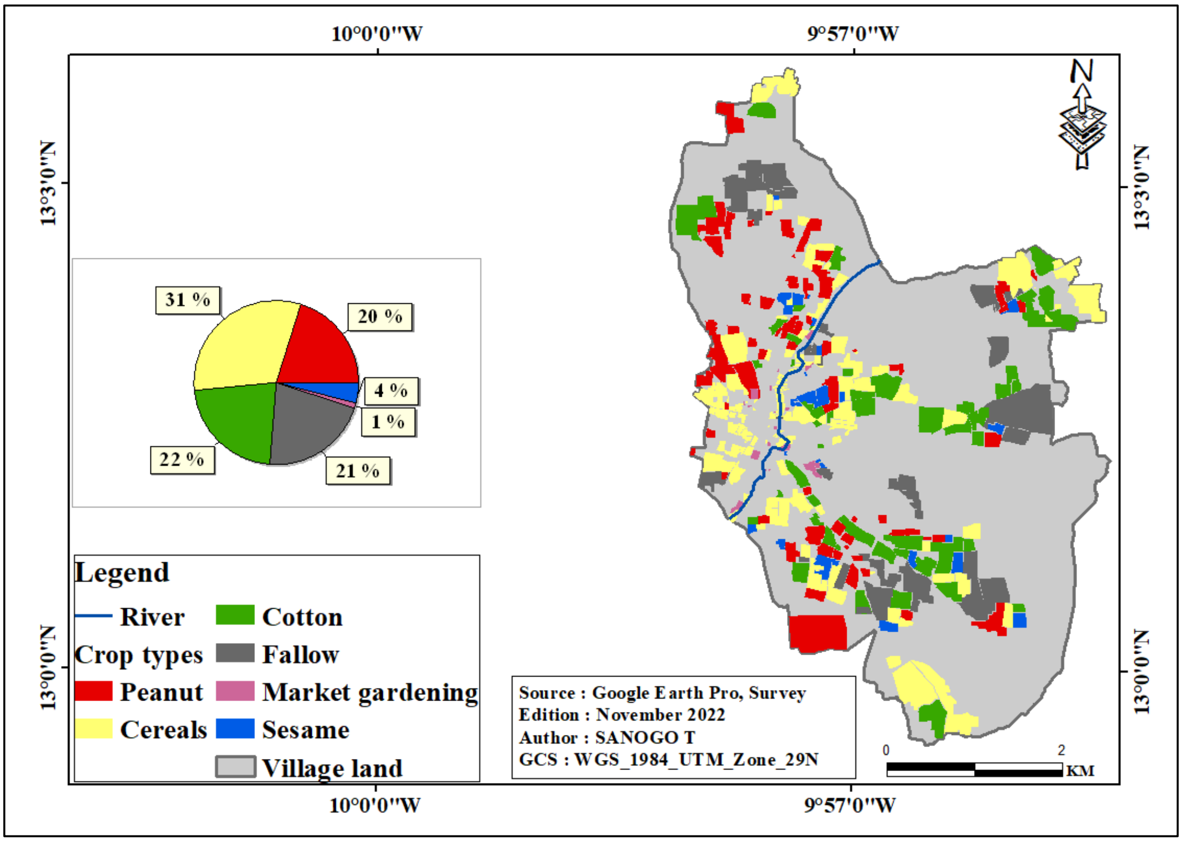

Fig.6: Distribution of crops in Madina Malinké during the 2020-2021 agricultural season

Also in the East, we observe a strong presence of cotton plots and certain cereal plots. On the other hand, in the west of the region, there is a strong dominance of plots of food crops and a few plots of peanuts.

During this campaign, the area of cereal crops fell significantly in favor of cotton cultivation. During the 2019-2020 agricultural campaign, the cereal area was 42% compared to 31% during the 2020-2021 agricultural campaign (**Fig.6**). In the case of cotton, the allocated area constituted 14% against 22%. As for peanut and sesame crops, they did not experience a big change with 20% and 5% respectively. On the other hand, there are more plots left fallow (i.e. 21%).

3.2 Mapping of Toufinko crop rotations during the 2019-2020 and 2020-2021 agricultural seasons

In the Toufinko region, the cropping system is characterized by a dominance of sesame and cereal cultivation. Following the soil conditions which offer very limited potential for agricultural practices, crops are mainly located in the river bottom. During the 2019-2020 agricultural campaign, in the center of the land (the village site) we observed a dominance of plots growing cereals (**Fig.7**). In the South, cereal plots are mainly presented with sesame and some cotton plots. In the West, peanut plots are the most representative with sesame and cereals.

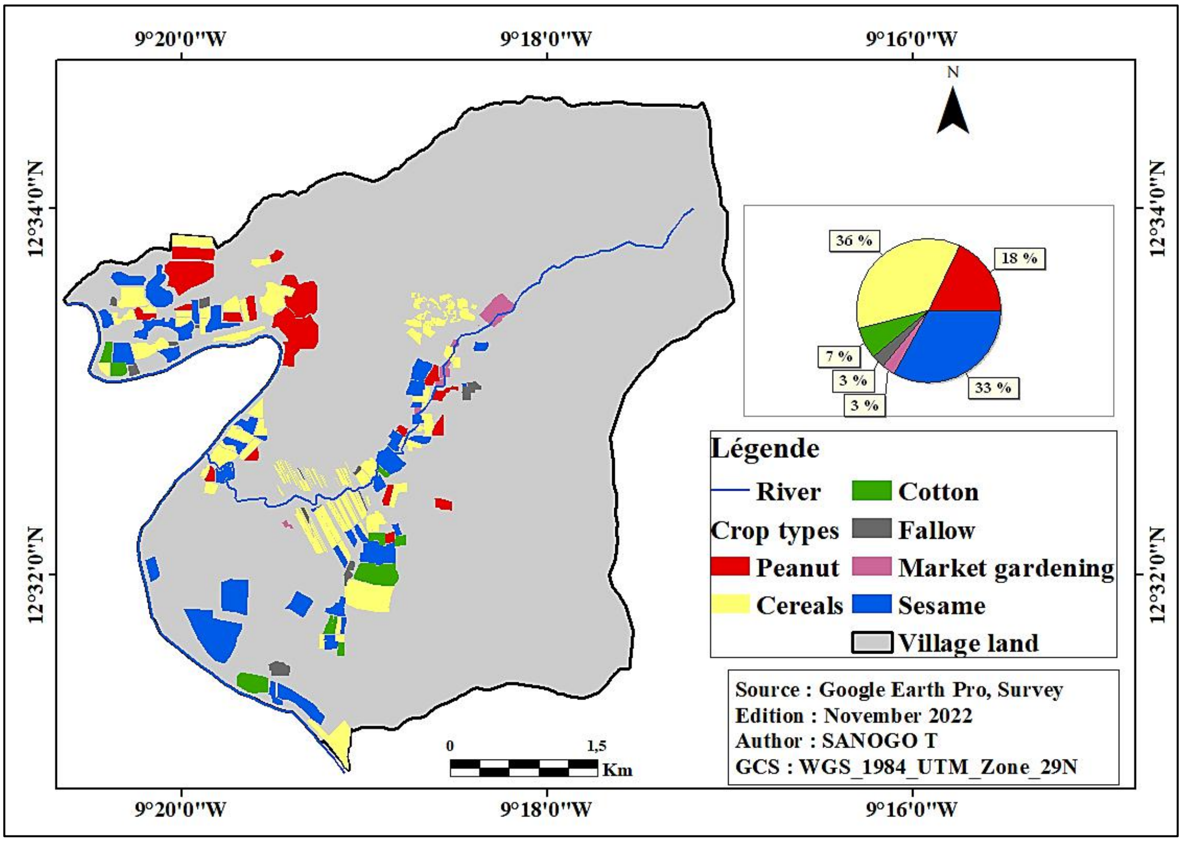

Fig.7: Distribution of Toufinko crops during the 2019-2020 agricultural season

In Toufinko, cereals and sesame are the most dominant with the largest areas during the 2019-2020 agricultural campaign with respectively 36% and 33% of cultivated areas. Peanuts comprise 8%, cotton 7% and vegetable crops constitute 3%.

The spatial distribution trend of crop types during the 2020-2021 agricultural campaign remains similar to the previous agricultural campaign (**Fig.*8***). Around the houses in the center of the land, it remains exploited for the cultivation of cereals, in the South the sesame and cereal plots are located and the same reality is observed in the West.

Likewise, statistically, the areas per type of crop have experienced small changes. The areas intended for cereals are 38% of cultivated land, sesame cultivation represents 31%, peanut plots occupy 14%, cotton cultivation constitutes 10% and 4% of cultivated land is fallowed.

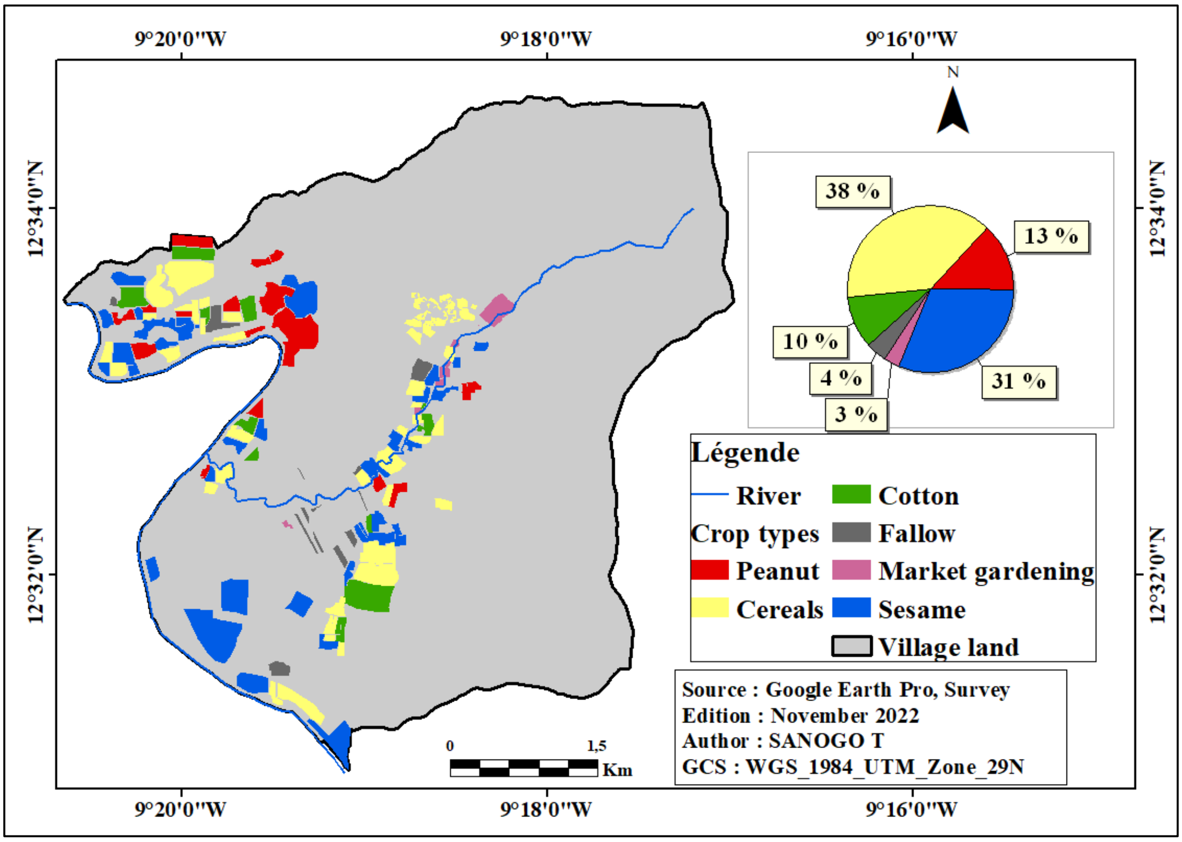

Fig.8: Distribution of Toufinko crops during the 2020-2021 agricultural season

IV. DISCUSSIONS

The acquisition of agricultural information on what is produced (types of crops) in time and space constitutes a major asset for carrying out this research. Indeed, having such information is a springboard for agricultural monitoring, particularly in the context of food security. Thus, maps of crop types over two agricultural seasons in the terroirs of Banfara, Madina Malinké and Toufinko were established with very great precision. This constitutes one of the great strengths of this work. However, the mapping of crop types in agricultural landscapes in Africa is mainly limited by its heterogeneous composition, lack of temporal data and cloud cover (Kpienbaareh et al., 2021). Furthermore, the accuracy of classification of crop types through classification algorithms rarely exceeds 80% correspondence of trained results to field data (You et al., 2021).

The maps produced made it possible to understand the cropping systems practiced in these areas based on the crop rotation maps for the 2019-2020 and 2020-2021 agricultural seasons. The results show that the Banfara cultivation system is characterized by a dominance of cotton and peanut cultivation (**Fig.*4***). Previous studies confirm that the Sudano-Guinean zone of Mali is characterized by an agricultural system dominated by cotton, which constitutes the primary cash crop in the zone (Vintrou, 2012). In Madina Malinké the cultivation system is mainly composed of cereals followed by peanuts and cotton (**Fig.*6***). These results corroborate with those of Kpienbaareh et al., 2020 in Malawi where crop distribution is mainly dominated by maize. However, in Toufinko, it is mainly dominated by sesame cultivation (**Fig.*8***). Which means that the cropping systems of these three areas are strongly dominated by cash crops (cotton, peanuts and sesame) except in Madina Malinké (sorghum, millet and peanuts). Furthermore, according to Dembele, 2018 the cultivation systems in the cotton zone in Mali are characterized by a very great diversity of crops which allows a distribution of economic and environmental risks. The research results of Konduri et al., 2020 show a possibility of crop mapping with more or less acceptable precision. These authors assert that cereal crops largely constitute the US cropping system.

The participatory approach to crop mapping carried out using very high spatial resolution images constitutes a great asset of this research. This method above all made it possible to take into account the actual size of the plots but to avoid possible errors of confusion with the type of cultivation practiced on the plots. However, despite the subtlety of reading Google Earth images, producers could be mistaken about the succession of crops on a plot during the different agricultural seasons.

V. CONCLUSION

This research presents the contribution of geospatial technologies to participatory mapping of crop rotation. The results show a great performance of this combined approach. The main crops in Banfara are cotton which exerts great pressure on other crops, followed by peanuts and sorghum. Banfara's cropping system is dominated by sorghum, peanuts and cotton in Madina, however, the main crop is sesame in Toufinko. Additional research is necessary to assess the agricultural production capacities of these localities.

REFERENCES

[1] Baro, J., Méring, C., & Vachier, C. (2014). Peut-on cartographier des taches urbaines à partir d'images Google Earth ? Une expérience réalisée à partir d'images de villes d'Afrique de l'Ouest. *Cybergeo : Revue européenne de géographie / European journal of geography*, *682*, Online. https://doi.org/10.4000/cybergeo.26401

[2] Bellon De La Cruz, B. (2018). Une approche multiscalaire par télédétection pour la cartographie et la caractérisation des systèmes agricoles à l'échelle régionale (Brésil) [Thesis, Université de Montpellier]. https://agritrop.cirad.fr/589308/

[3] Chen, Y., Lu, D., Moran, E., Batistella, M., Dutra, L. V., Sanches, I. D., da Silva, R. F. B., Huang, J., Luiz, A. J. B., & de Oliveira, M. A. F. (2018). Mapping croplands, cropping patterns, and crop types using MODIS time-series data. *International Journal of Applied Earth Observation and Geoinformation*, *69*, 133-147. https://doi.org/10.1016/j.jag.2018.03.005

[4] Choplin, A., & Lozivit, M. (2019). Mettre un quartier sur la carte : Cartographie participative et innovation numérique à Cotonou (Bénin). *Cybergeo: European Journal of Geography*, En ligne. https://doi.org/10.4000/cybergeo.32152

[5] Cormier - Salem, M.-C., Descroix, L., & Diakhaté, M. M. (2017). Sciences participatives, gouvernance des patrimoines et territoires des deltas : Actes du colloque International du Laboratoire Mixte International « Patrimoines et Territoires de l'Eau » : Du 11 au 14 mai 2016 à l'Université Gaston Berger de Saint-Louis du Sénégal. 1-376.

[6] Dembele, S. (2018). *Structuration spatiale de la biodiversité agricole dans la zone cotonnière du Mali* [Thèse de Doctorat en Géographie, Normandie Université]. https://tel.archives-ouvertes.fr/tel-03085785

[7] INSTAT-MALI. (2009). Résultats définitifs, répertoire des villages (4e Recensement général de la population et de l'habitat du Mali), RGPH (p. 318). Institut national de la statistique.

[8] Konduri, V. S., Kumar, J., Hargrove, W. W., Hoffman, F. M., & Ganguly, A. R. (2020). Mapping crops within the growing season across the United States. *Remote Sensing of Environment*, *251*, 112048. https://doi.org/10.1016/j.rse.2020.112048

[9] Kpienbaareh, D., Bezner Kerr, R., Luginaah, I., Wang, J., Lupafya, E., Dakishoni, L., & Shumba, L. (2020). Spatial and Ecological Farmer Knowledge and Decision-Making about Ecosystem Services and Biodiversity. *Land*, *9*(10), 1-24. https://doi.org/10.3390/land9100356

[10] Kpienbaareh, D., Sun, X., Wang, J., Luginaah, I., Bezner Kerr, R., Lupafya, E., & Dakishoni, L. (2021). Crop Type and Land Cover Mapping in Northern Malawi Using the Integration of Sentinel-1, Sentinel-2, and PlanetScope Satellite Data. *Remote Sensing*, *13*(4), Article 4. https://doi.org/10.3390/rs13040700

[11] Lefebvre, F., Bonnet, E., & Boyer, F. (2017). Une méthode de cartographie participative des pratiques et représentations urbaines à Ouagadougou (Burkina Faso). *EchoGéo*, *40*, Article 40. https://doi.org/10.4000/echogeo.14978

[12] Ouyang, F., Su, W., Zhang, Y., Liu, X., Su, J., Zhang, Q., Men, X., Ju, Q., & Ge, F. (2020). Ecological control service of the predatory natural enemy and its maintaining mechanism in rotation-intercropping ecosystem via wheat-maize-cotton. *Agriculture, Ecosystems & Environment*, *301*, 1-7. https://doi.org/10.1016/j.agee.2020.107024

[13] PDSEC. (2021). Plan de Développement Socio-Economique et Culturelle de la commune de Kobri 2021-2025 (p. 172).

[14] Pittman, K., Hansen, M. C., Becker-Reshef, I., Potapov, P. V., & Justice, C. O. (2010). Estimating Global Cropland Extent with Multi-year MODIS Data. *Remote Sensing*, *2*(7), Article 7. https://doi.org/10.3390/rs2071844

[15] San Emeterio, J. L., & Mering, C. (2021). Mapping of African urban settlements using Google Earth images. *International Journal of Remote Sensing*, *42*(13), 4882-4897. https://doi.org/10.1080/01431161.2021.1903613

[16] Traoré, S., & Le Bars, M. (2018). L'APPORT DE LA CARTOGRAPHIE PARTICIPATIVE POUR REPRESENTER LES TERROIRS AGRICOLES AU MALI. *Cartes et Géomatique*, *235*, 201-208.

[17] Vintrou, E. (2012). *Cartographie et caractérisation des systèmes agricoles au Mali par télédétection à moyenne résolution spatiale* [Thèse de Doctorat en Géographie, l'Institut des Sciences et Industries du Vivant et de l'Environnement (AgroParisTech)]. https://pastel.archives-ouvertes.fr/pastel-00781223

[18] Wei, Y., Lu, M., Wu, W., & Ru, Y. (2020). Multiple factors influence the consistency of cropland datasets in Africa. *International Journal of Applied Earth Observation and Geoinformation*, *89*, 1-11. https://doi.org/10.1016/j.jag.2020.102087

[19] You, N., Dong, J., Huang, J., Du, G., Zhang, G., He, Y., Yang, T., Di, Y., & Xiao, X. (2021). The 10-m crop type maps in Northeast China during 2017–2019. *Scientific Data*, *8*(1), 41. https://doi.org/10.1038/s41597-021-00827-9