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Design of a Relational Database for the Management of Crop Residues in Agricultural Regions: Case of the Agricultural Basin of Sassandra – Ivory Coast

Amenan Anne Mary Kouassi-kouadio[1, *], Petemanagnan Jean-Marie Ouattara[1], N'Da Akoua Alice Koua-Koffi[2], Talnan Jean Honore Coulibaly[3], Lacina Coulibaly[1, 4]

[1]Laboratory of Environment and Aquatic Biology, Department of Sciences and Environment Management, Nangui Abrogoua University, Abidjan, Ivory Coast

[2]Department of Agronomic, Forestry and Environmental Engineering, University of Man, Man, Ivory Coast

[3]Laboratory of Geoscience and Environment, Nangui Abrogoua University, Abidjan, Ivory Coast

[4]Laboratory of Environment and Aquatic Biology, Department of Sciences and Environment Management, University of Man, Man, Ivory Coast

Email address:

mimoyek@yahoo.fr (Amenan Anne Mary Kouassi-kouadio), jm_petemanagnan@yahoo.fr (Amenan Anne Mary Kouassi-kouadio)

[*]Corresponding author

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Abstract: The management of crop residues remains a major concern for the populations of regions with strong agricultural activity, because their poor management is often a source of disease. Also the absence of a consolidated database of the quantities of agricultural waste actually produced in the localities makes it difficult to exploit them. This work aims to set up a relational database making it possible to obtain information on the quantities of residues available in the localities. The quantities were estimated using agricultural statistics data from the Ministry of Agriculture and residue productivity indices. The approach adopted is the MERISE method which requires a study of the existing as well as a formalization based on the entity-association model and the use of a relational database management system, then a programming language oriented object. The result of this work is a user-friendly interface that makes it easy to enter and to view crop residue data. Thus, the "bddechetagro" database set up contains useful data for an overall assessment of the problem. She will allow operators wishing to process crop residues in recovery units to acquire information on the desired residues. Thus, from a query, it is possible to obtain the list of residues available in the basin, residues available in a locality, residues available by locality and by type of residue, information on a residue from the name, to obtain information from a producer of residue.

Keywords: Data Modeling, Merise, Database, Sassandra Watershed, Ivory Coast

1. Introduction

Since the early 1990s, environmental protection has become a major topic and a collective concern in our society [1]. The issue of waste is daily and affects each individual both professionally and familiarly. Crop residues have long been considered waste that had to be disposed of in order to plant new crops. However, with the ecological considerations related to global warming, these residues find their interest in crop rotations for their positive actions on the maintenance of the stock of organic matter in the soil [2, 3]. They allow soil stability in the face of anthropogenic and climatic aggressions, and contribute to providing nutrients to subsequent crops during their degradation by carbon storage [4]. In the field of agricultural waste management in Africa, there is little consolidated database of residues [5], which could allow any economic operator wishing to recover them to find out about the availability of these so-called waste. These recovery practices make it possible to mitigate the environmental

impacts associated with this waste. In Ivory Coast, little work has been done on the creation of databases for real-time storage of the amount of agricultural waste actually produced in areas with high agricultural activity. However, databases have taken an important place in the field of management. She makes it possible to provide information from formulated requests, said requests which can be formulated in the form of queries [6]. The Sassandra watershed is an agricultural zone of the country [7]. This study aims to establish a reliable and rustic database of agricultural waste in this area where agriculture remains the main activity.

2. Materials and Methods

2.1. Study Area

The Sassandra watershed is located in the west of Ivory Coast. It covers an area of approximately 75,000 km^2 [8]. and is located between longitude 5°75 and 8°16 West and latitude 5° and 9°75' North. The main watercourse of this watershed is the Sassandra River. It is 650 km long and has its source in the region of Beyala in Guinea, under the name of Ferédougouba [8]. This study concerned the southern part of the WS which includes the departments of Daloa, Issia, Soubré and Sassandra. Figure 1 below shows the departments concerned by this study. These localities have an area of 34338.76 km^2. their total population is estimated at 1518594 inhabitants [9]. The economic activities carried out in these different localities are: agriculture, trade and transport. However, agriculture remains the main economic activity, practiced by 60% of the population [9]. The agricultural dynamic is essentially based on cash crops (coffee, cocoa, rubber, oil palm), food crops and market gardening.

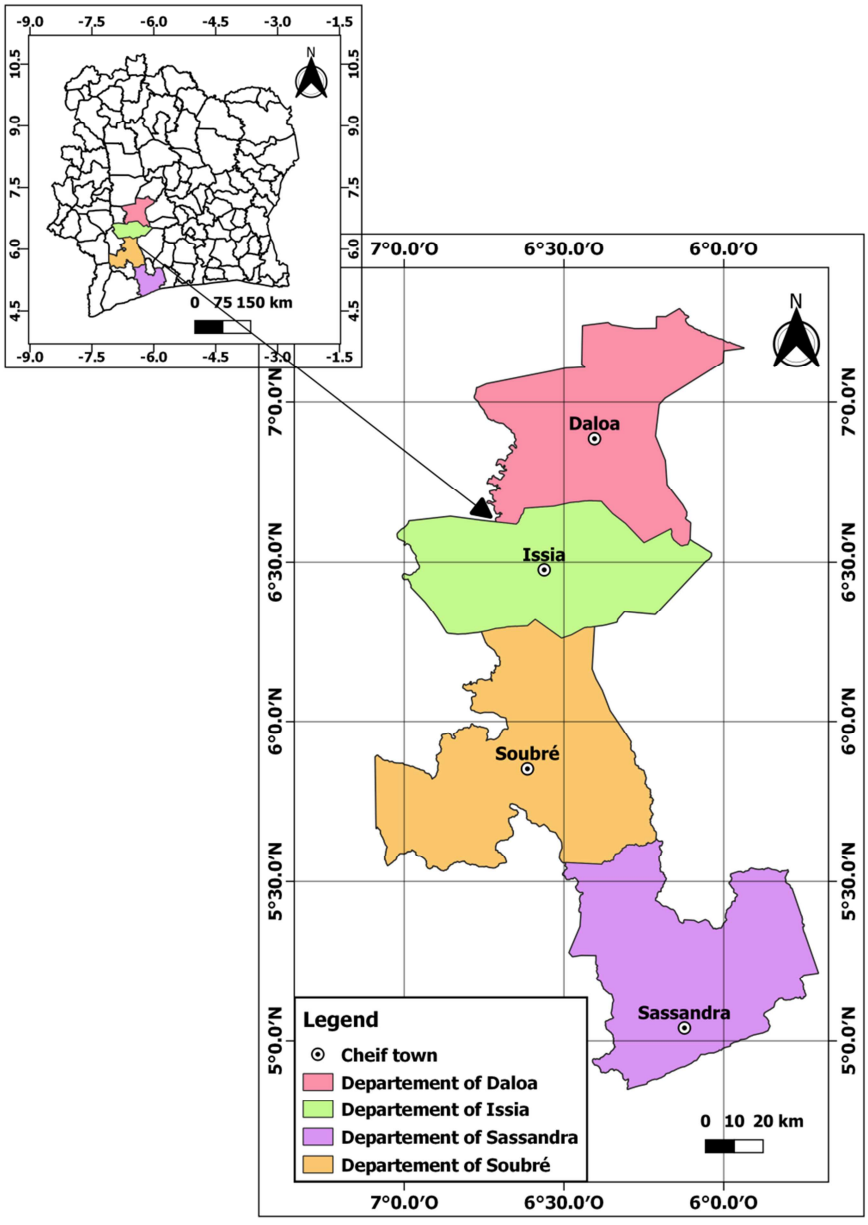

Figure 1. *Study area localization.*

2.2. Material

The material used for the development of this study consists of agricultural statistical data provided by the Department of Statistics, Documentation and Information Technology of the Ministry of Agriculture of Ivory Coast. Several softwares were used in particular, Power AMC 15.5 for the conceptual modeling of the data, the relational database management system My SQL for the creation and the management of the database and PHP for the creation of the forms allowing a fast entry and clear from the data.

2.3. Method

2.3.1. Estimation of the Quantities of Crop Wastes

The quantities of residues (QR) from the crops were determined from the relation (1) described according to FAO [10].

$$QR = m \times Cres \quad (1)$$

Where:

m: Mass of the production for the considered crop (kg),

Cres: Coefficient relating to the quantity of residues generated according to agricultural production.

The values of Cres are consign in Table 1.

Table 1. *Cres values FAO [10].*

Wastes typology by culture		**[10]**
Cultures	**Wastes**	**Cres**
	Straw	1.757
Rice	*Husk*	0.267
	Stalk	0.20
Maize	*Cob*	0.273
	Stem	2.00
	Cluster	0.23
Palm oil	*Fibre*	0.14
	Shell	0.065
Cocoa	*Pods*	1.00
Coffee	*Shell*	2.10
Cassava	*Stem*	

2.3.2. Database Conception

The analysis method used is the MERISE method. It is a method of analysis, design and management of IT projects. It has the functionalities of relational databases [11].

Conceptual model

This step consisted in carrying out a complete analysis of the information and organizing it. The Conceptual Data Model made it possible to define the objects of the Information System as well as the links that exist between them. Thus, the entities were determined taking into account the content of the database. The conceptual model was designed according to the Entity-Relationship formalism. A list of information devoid of redundancies, synonyms, polysemy and homonyms has been produced. Each item of information has been associated with a description in the form of free text and possibly keywords, in order to constitute a catalog of information called a data dictionary. Only relevant and existing data for the development of the database on the targeted theme but also likely to be collected have been retained. [12]

1) Logical data model

The logical data model consisted of simplifying the CDM diagram from a set of transformation rules established by the MERISE method [13].

2) Relational Database

The computer database was created and managed by a MySQL Relational Database Management System designed around the mathematical concepts of relational algebra linking two-dimensional data tables and SQL language concepts [14]**.** is illustrated. The approach adopted to design the database illustrated by figure 2.

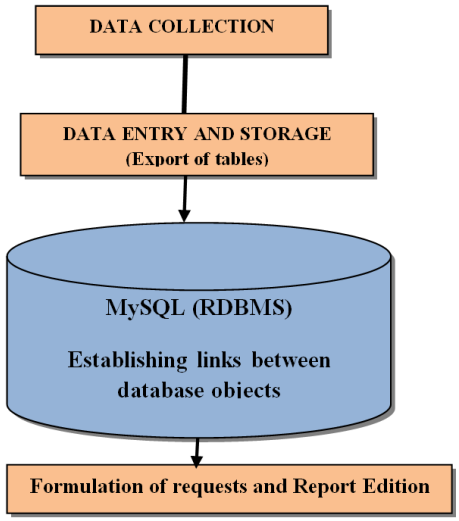

Figure 2. *Conceptual flowchart of creating a database Nanci et al. [14].*

3) Realization of a prototype

After defining the overall functioning of the system using modeling, a prototype is proposed. It is an exploratory system involving a restricted set of analysis functions. The use of a prototype is an effective means that has made it possible to specify the concepts, experiment and make strategic choices. The prototype implements different scenarios for using the information system. Its operation consists of interrogating the database using the SQL language and obtaining the desired information. It was produced using PHP software. It is an easy-to-use tool, where forms allow quick and clear data entry. Data consultation is also a focal point for users.

3. Results

3.1. Estimation of Crop Residue Quantities

Waste from cocoa, coffee, oil palm, rice, cassava and maize crops mainly consist of straws, clusters, stalks, cocoa pods, fibers, ears, shells and cobs (Tables 2 and 3). The data

obtained show that the towns of Soubré, Sassandra, Issia and Daloa are full of large quantities of agricultural residues. However, these are higher at Soubré (290,000 t). This locality is followed by that of Daloa with 236,123.3 t, then that of Issia with nearly 255,000 t. The locality of Sassandra has the lowest quantities of resudues (198,221.4 t). The total quantity of agricultural residues that can be mobilized in these localities is 930,220.865 t.

Table 2. *Different amounts of residue.*

Localities	Pod	Cluster	Fiber	Shell	Husk	Straw	Stem	Cob	Stalk
Daloa	16118,65	794,65	483,7	1130,0719	5073	33383	145058,29	19671,01	14411
Issia	132244	1282,48	780,64	41900,44	1565,55	10302,16	13829,33	1822,06	1334,84
Sassandra	44638	8910,2	66666	37014,8	3019,99	19873,14	14695,614	1964,50	1439,2
Soubre	272265,65	0	0	4234,8936	1869	12299	0	0	0

Table 3. *Amount of residues by crop type.*

Localities	Coffee	Cocoa	Oil palm	Rice	Maïze	Cassava
Daloa	905,4969	16118,65	1502,925	57 456	178192,015	948,29
Issia	41538	132244	2425,56	17731,224	16505,3708	480,872
Sassandra	34496,7	44638	78094,3	34203,9802	17795,708	303,614
Soubre	4234,8936	272265,658	0	21168	0	0
total	81175,0905	465266,308	82022,785	130559,204	212493,094	1732,776

3.2. Database Design

3.2.1. Conceptual Diagram

The conceptual data model developed is shown in figure 3. It shows seven (7) relevant objects of the information system which are: plantation, planter, production, village, town, waste, type of plantation. As well as seven (7) relationships (implant, have, have2, produce, understand, understand1, locate). On this conceptual diagram, the pair (1,1; 1, n) or (0,1; 1, n) represents the number of times that an object participates in a relation between at least two of these objects (the cardinalities).

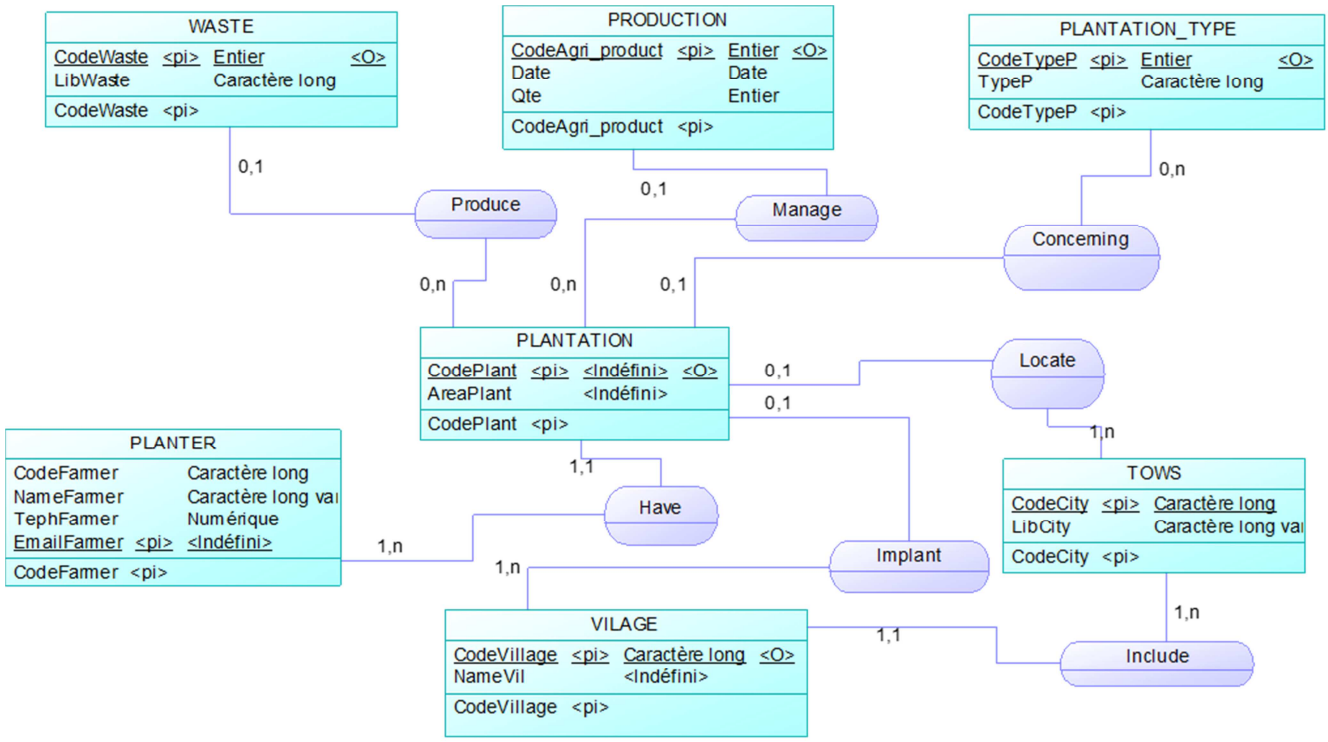

Figure 3. *Conceptual Diagram of Data under Power AMC.*

3.2.2. Database Administration Interface

Figure 4 shows the structure of the database with MySQL. In the home interface, the user has all the tools provided by MySQL to create and administer the databases.

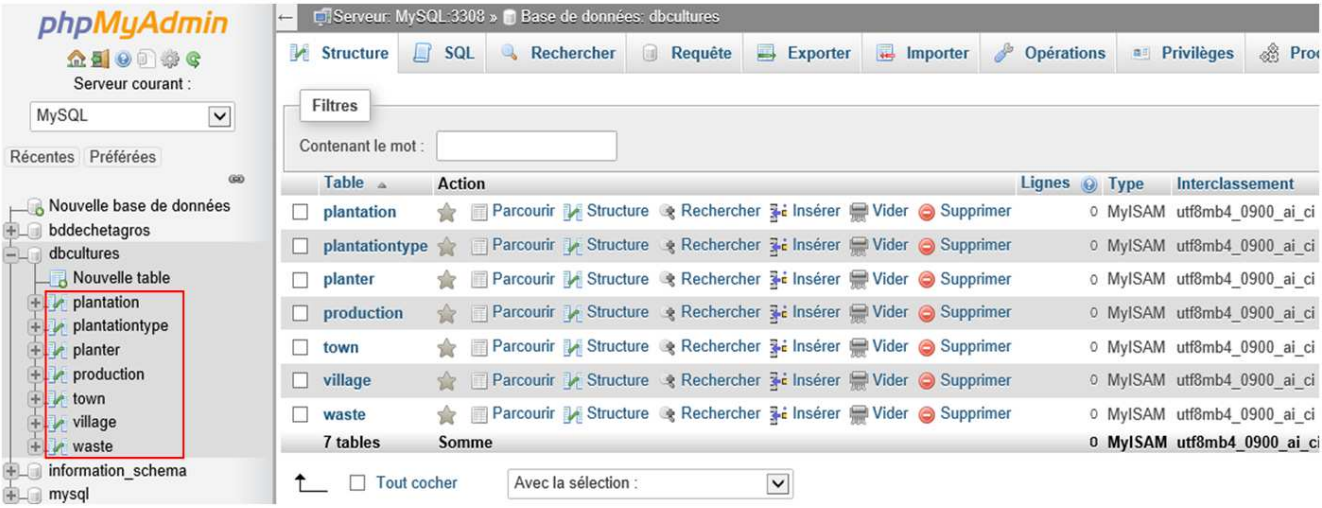

Figure 4. *Structure of the database.*

3.2.3. Home Page

Figure 5 shows the home page of the database on which the "Add" and "Search" menus are located. The "Add" menu allows to connect to the database in order to add residues. These include bunches, fibers, shells, pods, straws, husks, cobs, stalks and stems existing in the departments of Soubré, Sassandra, Issia and Daloa. The "Search" menu allows to search for residues. This search can be done from the residue wording. The "Search" menu allows to formulate queries concerning a type of residue, the quantity available, information on the planter who holds the residue. For example, from the search menu, we can have the list of residues, List of available residues according to a given locality, the list of residues from the name of residues, the list of available residues by locality and by type of residue.

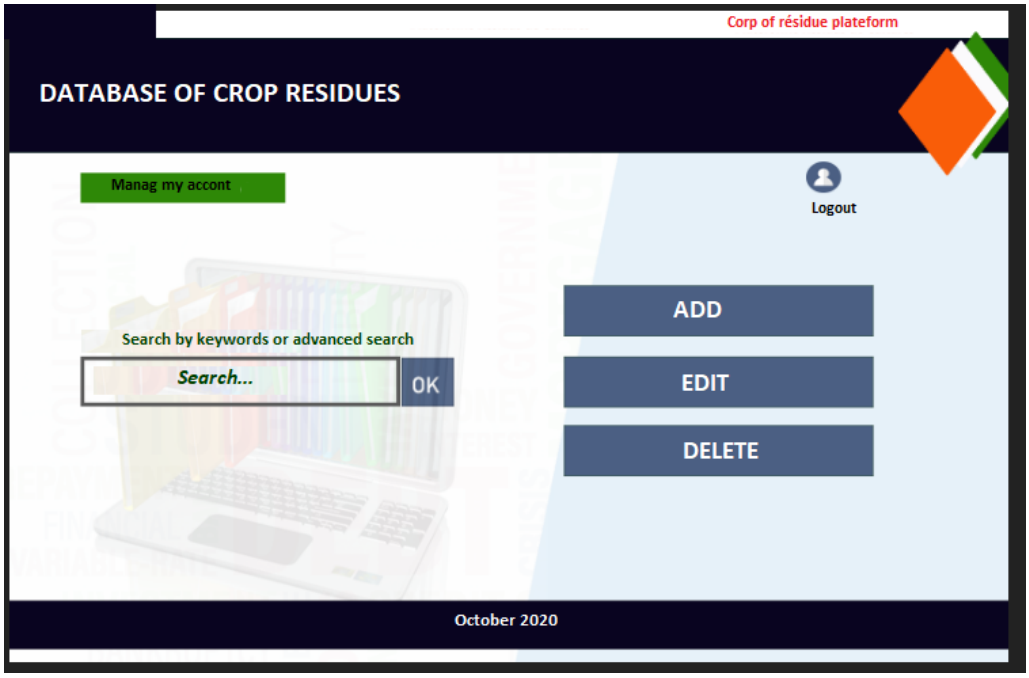

Figure 5. *Database home screen created with EasyPHP.*

Exploitation of the prototype

The information from the exploitation of the prototype is presented in the form of tables and statistics. The exploitation of this prototype through three example of queries will make it possible to obtain the list of residues available in the basin, residues available in a given locality, residues available by locality and by type of residue.

Query I: What are the tailings and their quantities available in the Sassandra basin.

The entire query in SQL is written as follows in the query editor:

```
select (' plantation.superficieplant,
village.nomvillage,
wast.namewast,
```

```
townname,
qteproduction,
dateproduction')
->from ('plantation')
->join('village','plantation.Idvillage = village.Idvillage')
->join(town,'plantation.Idtown = town.Idtown')
->join('production','production.Idplantation = plantation.Idplantation')
->join('wast',' wast.Idtplantation = typeplantation.Idtplantation')
```

This query is run from the tables plantation, village, city, waste and production. The join between these tables is done in front of the "Join" operator to indicate to the system that there is a link between all these tables. Executing this query gives the list of waste available in the basin (Figure 6). For example, we can see that the department of Soubré precisely in the village of Yebouékro, the plantation (codeplant) has 10 t of dry cocoa pod. The numbers (1), (2), (3), (4) indicate that the result is displayed on four (4) pages.

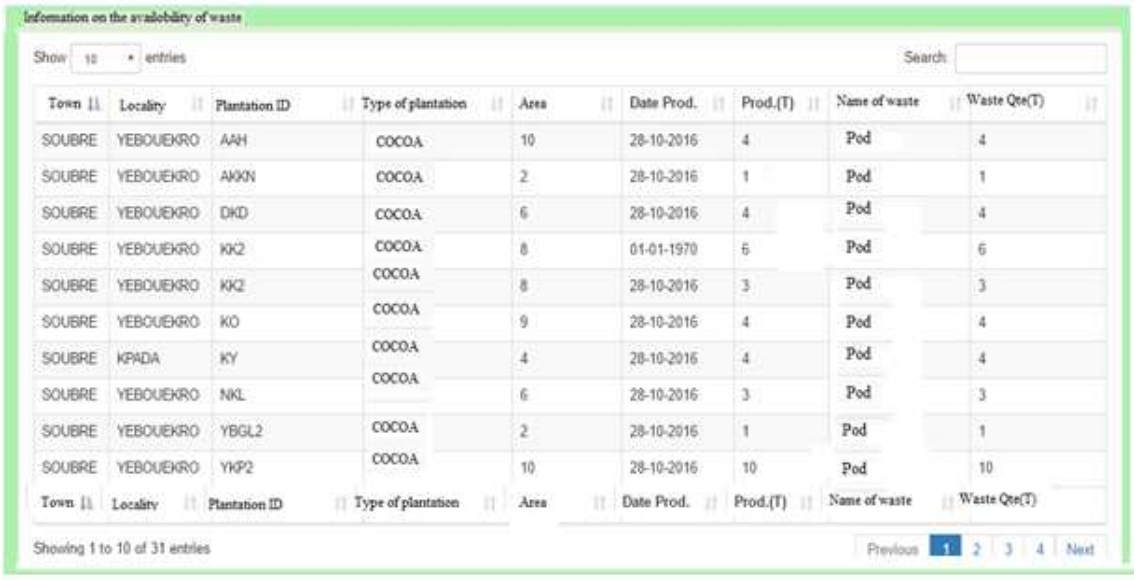

Figure 6. *List of available residues available in the basin.*

Query II: What are the residues available in a given locality?

This query takes into account a search criterion which is the name of a city for which we want to have information on the availability of residues. The user fills in the search field of the form by entering the name of the city and then clicking on the OK button.

For example, if the user enters SOUBRE the following query will display the list of waste available in the city of Soubré (figure 7).

Figure 7. *List of residues available in Soubré.*

Query III: What is the information about a residue type from a given residue name?

Here, the query to a search criterion which is the name of the residue. The entire query in SQL is written as follows:Select (' plantation.superficieplant,
village.villagename,
(dehet)., ?
townname,
productionqte,
dateproduction')
->from ('plantation')
->join('town','plantation.Idvillage = village.Idvillage')
->join('town','plantation.Idtown = town.Idtown')
->join('production','production.Idplantation = plantation.Idplantation')
->join('wast',' wast.Idtplantation = typeplantation.Idtplantation')
- >where('wast.wastname',$wastname);

The result of this query is presented in Figure 8. It is obtained by typing ears in the search section of the form and clicking on the OK button It shows that in Issia, precisely in Gboguedia, there are 1.638 t of corn cobs and 0.546 t of cobs in Soubré in the village of Yobouékro. Besides, the village of Kouassikankro has none.

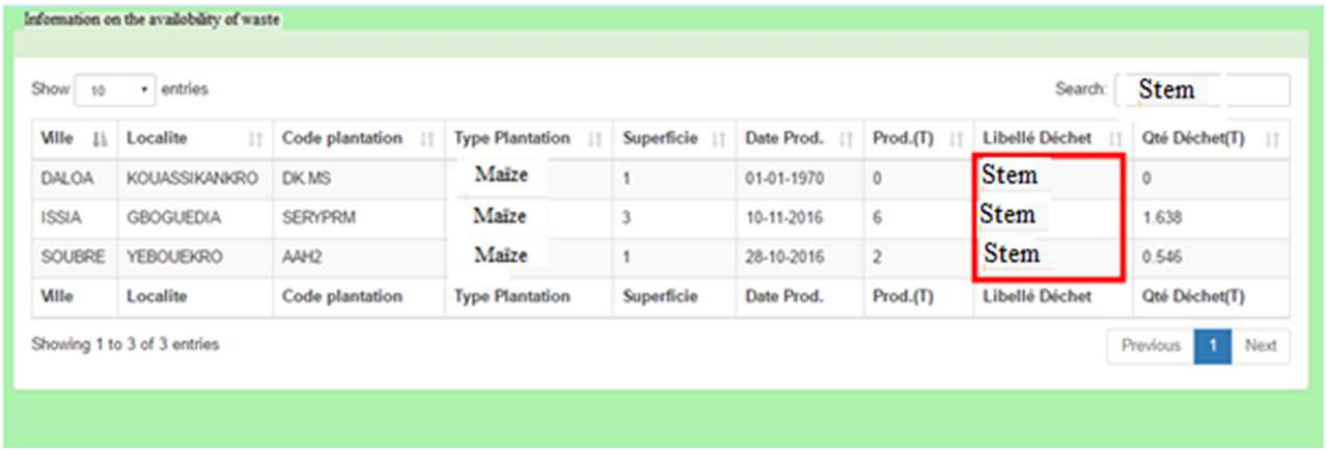

Figure 8. *List of a residue type.*

4. Discussion

This study made it possible to set up the database of agricultural waste in the southern watershed of Sassandra.

The agricultural waste estimated in this study comes from the crops of cocoa, coffee, oil palm, rice, cassava and maize. The south of the agricultural basin of Sassandra is full of a large deposit of agricultural residues. This would be due to the climatic conditions of the area which would be favorable to agriculture. This result confirms those of Coulibaly et al. [15] obtained in the same area. The highest quantities are recorded in the town of Soubré (290,000t). This locality is followed by that of Daloa with 236,123.3 t of waste, then that of Issia with nearly 255,000 t of waste. The locality of Sassandra has the lowest quantities of residues with 198,221.4 t. The total quantity of agricultural residues that can be mobilized in these localities is 930,220.865 t. This information can be stored in a database to be used for better decision making. In the same perspective, Konan-Waidhet *et al.* [16] stored information on drilling locations in the Denguélé region in a database to facilitate the selection of drilling sites.

Regarding the database of agricultural waste, it was developed from the Method of Study and Computerized Realization of Subsets (MERISE). The use of this method would be explained by the fact that it makes it possible to obtain a Conceptual Data Model (CDM) which presents the relations which exist between the various objects of the information system. This makes the task easier for both advanced users and non-specialists in data modeling. Konan-Waidhet et al. [17] also modeled a database for analyzing the productivity of fissured aquifers in the Dioulatiedougou region using the MERISE method. In addition, the simplicity and readability of the MCD obtained from MERISE, promotes the consistency of the data that will be inserted into the database, as well as the longevity of the model [13]. The readability of the CDM of the "bddechetagri" database obtained from the MERISE method facilitates its creation, maintenance and evolution [18]. MERISE is the method of analysis, design and development of information systems prized and recommended by professional analysts in the French-speaking computer world. For this study, we used as a software engineering workshop (AGL) the software SAP PowerDesigner formerly PowerAMC from Sybase or AMC Designer. The choice of the AGL PowerDesigner from Sybase would be explained by the fact that PowerDesigner from Sybase is a design tool, in particular those associated with Merise. Nanci et *al.* [14] have also affirmed this in their book "Engineering of information systems: Merise second generation". The database of the agricultural basin of Sassandra (bddechetagri) contains useful data for an overall assessment of the problem of crop residues. Indeed, in its design the bddechetagri takes into account all aspects of

agricultural waste management. The Relational Database Management System (RDBMS) MySQL was used to design the database (bddechetagri), However, for such a database, another database management system platform such as DBMS Microsoft MS Access, Oracle, DB2 could be used [17]. The choice of MySQL finds its explanation at the level of the study of the existing. Indeed, MySQL is available in the Appach server of EsayPHP and wampServer and better adapt with the applications which work in Web environment. Also according to Sahri [19] and Coulibaly [20] MS Access is used for relatively small databases. Moreover, according to Thiamet al. [21], Oracle is the most suitable DBMS for spatio-temporal databases. The choice of MySQL would also be explained by the fact that the objective of our study is to propose a reliable solution that meets the needs while minimizing as much as possible the costs related to the implementation of the database while guaranteeing a good security. In addition, MySQL has a query editor that is better suited to applications that operate in a Web environment. Some advanced features, such as multi-master replication or MySQL is the best known open source relational database management system. MySQL's Query Editor executes all select, insert, update, and delete queries against the various tables in the database. Queries run against tables through joins. This query editor plays the same role as the SQL query editor used by Ghyselinck [22].

5. Conclusion

The use of the relational database management system has made it possible to develop a prototype for the exploitation of data on crop residues from the Sassandra agricultural basin. This prototype has been successfully tested to obtain the list of residues available in the database.

It can enable operators wishing to process crop residues in recovery units to acquire information on the desired residues. Thus, from a query, it is possible to obtain the list of residues available in the agricultural basin of Sassandra, the list of residues available according to a given locality, the list of residues available by locality and by type of residue and to search for information about a residue from the residue name.

This database, enriched by a multitude of queries, can serve as a guide for a new campaign for the recovery of agricultural residues.

6. Recommendations

We recommend setting up a platform that will allow producers of crop residues to fill in the database online.

In addition, that the prices be proposed in order to allow the economic operators to make their arrangements for any purchase of crop residues through the database.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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