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Dossier

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PART 1

Second and Third Generation Biofuels: Towards Sustainability and Competitiveness

Deuxième et troisième génération de biocarburants : développement durable et compétitivité

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Biomass Assessment: A Question of Method and Expertise

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Résumé — **Évaluation de la ressource biomasse : une question de méthode et d'expertise** — Alors que les objectifs non-alimentaires sur la biomasse ligno-cellulosique sont souvent orientés par la demande (chaleur, électricité, biocarburants, etc.) principalement *via* des politiques publiques, le nouvel équilibre dépendra également de l'offre. L'appréciation de cette offre est rendue complexe par la multiplicité des critères techniques, socio-économiques et environnementaux qui la définissent et/ou qu'on souhaite lui assigner. Elle renvoie ainsi ceux qui s'y essaient à l'étude de combinaisons croisant plusieurs thématiques : multi-ressources (agriculture, forêt, cultures dédiées, co-produits et déchets), quantités disponibles/potentiels et coûts, localisation, effet de substitution/changement (des activités/d'usage des sols) et comportement des parties prenantes de l'offre. De nombreuses initiatives ont été engagées pour capturer ces dimensions par différents projets (Agence Nationale de la Recherche, ADEME, etc.). Beaucoup de chiffres existent sur l'évaluation de la biomasse, mais ils ne sont pas toujours fiables et ne sont pas comparables du fait de différences dans les définitions, les champs pris en compte, les données, les paramètres, les niveaux géographiques, les unités utilisées, l'échelle temporelle, etc. Pour ce qui est de la caractérisation des chaines d'offre de la biomasse, les évaluations sont souvent incomplètes et manquent de références méthodologiques. Cet article vise à mettre en lumière les éléments clefs de la méthodologie et les barrières à lever afin d'obtenir une meilleure évaluation et une meilleure compréhension de la mobilisation de la biomasse pour répondre aux attentes des utilisateurs potentiels et des autorités publiques.

Abstract — ***Biomass Assessment: A Question of Method and Expertise*** — *Whereas the new stakes on lignocellulosic biomass are often demand-oriented (heat, electricity, biofuels, etc.) mainly through public policies, the new equilibrium will depend also on the supply-side. This supply has to be understood as socio-economic and environmental targets combining many topics: multi-resources (agriculture, forest, "dedicated coppices", by-products and wastes), available/potential quantities and costs, localisation, replacement/substitution effects (activities, lands), and supply-side stakeholders' behaviours. Many initiatives have been launched to grasp those dimensions through projects (National Research Agency, French Environment and Energy Management Agency, etc.). Many figures exist on the biomass assessment aspect but they are not clear enough and not comparable due to differences in definitions, scopes, data, parameters, geographical levels, reporting units, time-scale, etc. Regarding the characterisation of biomass supply chains, evaluations* *are often incomplete and lack methodological references. This article aims to focus on methodological key points and barriers to overcome, in order to get a better evaluation and understanding of biomass mobilisation expected by potential users and public authorities.*

GLOSSARY

ANR	*Agence Nationale de la Recherche* (National Research Agency)
ASP	*Agence de Service et de Paiement* (Service and Payment Agency)
BDAT	*Base de Données des Analyses de Terre* (Soil Analysis Database)
BDNI	*Base de Données Nationale d'Identification* (National Identification Database)
BTL	Biomass to Liquid
CAP	Common Agricultural Policy
CRPF	*Centre Régional de la Propriété Forestière* (Regional Centre for Forest Owners)
DM	Dry Matter
ECUS	Directory of key figures for the horse sector produced by the *Observatoire économique et social du cheval de l'Institut français du cheval et de l'équitation (Haras nationaux)*
FORDAQ	Forest marketplace
IFN	*Inventaire Forestier National* (National Forest Inventory)
IGN	*Institut Géographique National* (National Geographic Institute)
LCA	Life Cycle Assessment
MAAP	*Ministère de l'Agriculture, de l'Agroalimentaire et de la Pêche* (Ministry of Agriculture, Agribusiness and Fisheries)
MEDEM	*Ministère de l'Écologie, du Développement Durable et de l'Énergie* (Ministry of Ecology, Sustainable Development and Energy)
NUTS	Nomenclature of Territorial Units in European statistics
ONF	*Office National des Forêts* (National Forest Service)
PNER	*Plan National des Énergies Renouvelables* (National Plan on Renewable Energies)
PNRB	*Programme National de Recherche sur les Bioénergies* (National Research Programme on Bioenergies)
RGA	*Recensement Général Agricole* (General Agricultural Census)
SSP	*Service de la Statistique et de la Prospective* (Statistic and Prospective Office)
Toe	Tonne oil equivalent

INTRODUCTION

Faced with the climatic questions, energy and sustainable development requirements, biomass has been assigned numerous objectives. Public policies abound with medium and long term numeric objectives: + 21%, Factor 4 as well as other figures which, for the time being, have only one certain consequence: demand will rise. However, it is more difficult to know whether supply will be sufficient and what sources will be mobilised.

We may also legitimately ask the question of what is biomass. Interpretations vary and assessments of the supply, without mentioning the practical aspects of achieving the additional mobilisation, are also extremely different.

In addition, biomass demand is related to the development (or not) of industrial activities which can be grouped for simplicity under the term of "bioenergy sectors". Like all industrial developments, project profitability and long-term supply must be guaranteed. If biomass demand increases as rapidly as predicted by the objectives set, the other sectors of activity are likely to see their supplies highly disturbed and unbalanced: the food sector could see some of its products or land areas diverted for the production of biofuels; the wood sector is already suffering from competition for the material uses of some forest products, causing prices to rise. Since another objective for the wood sector is to mobilise a national resource for domestic uses more intensively and more efficiently, it does not seem as though there are any plans to base the development of these new sectors mainly on imports. Consequently, all industrial sectors based on a raw material (or the land producing it) likely to be used by the bioenergy sectors are concerned by the results of studies and prospectives on the agricultural or forest product resource.

How can domestic supply meet this additional demand? Various biomass research projects have investigated this question. The PNRB (National Research Programme on Bioenergies) launched in 2005 by the ANR (National Research Agency) played a key role in financing several of these projects. This programme initiated joint research actions between the two main biomass suppliers: agriculture and forestry. Waste and/or products at end of life complete the biomass portfolio taken into account when assessing resources. Biomass produced from agriculture and forestry, together with dedicated crops (dedicated to energy) are primary lignocellulosic resources, whereas waste and other related conversion products are known as secondary biomass.

The first section of the article describes some important French research projects that have focused on biomass in recent years. These projects can be classified according to three axes: assessment of resources, the biomass sector and prospective studies. Each axis is then described in the following sections. Development proposals are made throughout the article.

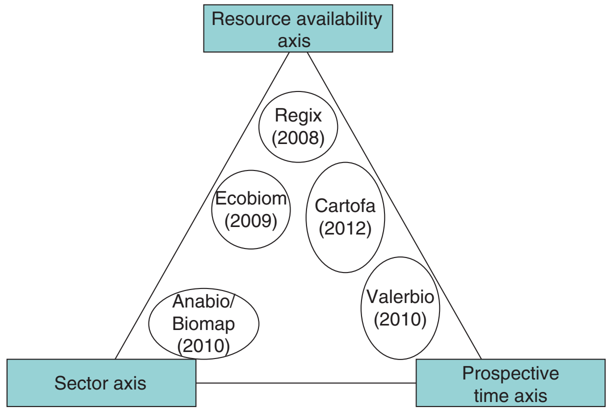

Figure 1

Distribution of the main biomass projects (final contractual year indicated) according to the axes: resource, sector and time.

1 PANORAMA OF EXISTING STUDIES

Over the last 10 years, a certain number of national research projects have discussed issues on forest and agricultural biomass availability from various and complementary angles. They include for example:

– REGIX: this project aimed at developing a unified approach to agricultural and forest lignocellulosic resources, know-how, techniques and methods for the biofuel sector. In particular, it led to the creation of a multicriteria repository of lignocellulosic resources, development and adjustment of biomass production and collection/logistics systems by experimentation and the improvement of biomass collection or source prediction tools;
– ECOBIOM: this project aimed to set up the tools required to define sustainable and appropriate conditions for the supply of agricultural and forest biomass to bioenergy (especially biofuel) production units. An original generic methodology for multicriteria optimisation of the agricultural and forest biomass supply at regional scale with a cantonal grid was produced, together with a map of the biomass sources in mainland French departments (NUTS3[1]) (quantities, costs, competition);
– ANABIO/BIOMAP: these projects concerned the development of a consistent multicriteria methodology used to assess and compare various bioenergy or bio-raw material production sectors, using different resources (agriculture, forestry, dedicated crop or waste). BIOMAP, carried out after ANABIO, consisted in testing the method to demonstrate its applicability to various problems of assessing the environmental and socio-technico-economic impacts, and the impacts on safety, of the bioenergy sectors;
– VALERBIO: the objective of this project was to collect all the information required for a theoretical integration of the biomass sector in MARKAL, a tool used to represent the various energy sectors, developed by École des Mines de Paris. The various potential production chains were therefore recreated and a prospective exercise initiated;
– CARTOFA: this project concerned a methodological analysis of studies on agricultural and forestry resources, a calculation of the current and 2020 availability, as well as an assessment of the need to introduce dedicated crops to reach the PNER (National Plan on Renewable Energies) objectives.

Globally, we observe in Figure 1, that studies on resource assessment and their methodology are most frequent, that the prospective is often present in these studies, while the global "sector" studies are rare. The resource and time studies are oriented on quantities and more rarely on cost/price. The sector studies have a strong multicriteria dimension. The spatial grid and the biomasses studied also represent discriminating factors in the studies and work conducted.

Potential users of these studies and more generally the existing international literature on the subject point out that it is difficult to obtain reliable data on the resources available for energy. It is true that the assessments often lead, at first sight, to contradictory results and prove difficult to use. Their analysis in fact reveals the striking lack of statistical sources dedicated to biomass (agricultural production, flows of wood and straw for example), heterogeneity and sometimes a lack of transparency in the data and methods used as well as varied expression of the results. Not forgetting the space-time dimensions, more or less clearly indicated and which vary depending

[1] French NUTS3 in the European Nomenclature for Territorial Units for statistics.

on the objective of the studies, sometimes making the results difficult to use.

Some projects include a comparison of the results of similar studies (resource, geographic area, time scale, etc.) within the scope of their study. ECOBIOM [1], Levesque *et al*. [2] had already discussed this issue. CARTOFA [3] includes a very extensive bibliographic analysis and has drawn the consequences for methodology. It nevertheless remains that coordination and consistency of the studies would be useful for everyone; this is the subject of an initiative entitled Bio-Osmose supported by research organisations within ANCRE (French National Alliance for Energy Research Coordination).

Figures 2 and 3 illustrate the variability of the results depending on the studies and the assumptions made.

It is therefore important to understand the differences between calculated and accessible resources, the way competing/preexisting, current and future uses are taken into account, whether or not the willingness to supply of the resource producers/holders is included in the assessment, and whether the mobilisation costs and other economic factors are included.

To answer these questions, the general principles are indicated in the following section and illustrated by the analyses and results of the latest project: CARTOFA [3].

2 BIOMASS RESOURCE STUDIES, A GREAT STEP TOWARDS MATURITY?

Both in France and internationally, several projects have focused on improving the agricultural and/or forest biomass availability calculation. More studies have been conducted on forest biomass since studies of the forest resource for wood availability, regardless of the use made, started earlier. The imbalance of the publications is clear, logically at the expense of agricultural biomass, mainly allocated until recently to food applications, with 10 times more studies on forest sources than agricultural sources. Since 2005, however, we have seen a major increase in this type of study in every field (80 studies on the forest resource out of a total of 500 listed).

Levesque *et al*. [2] analysed the forest resource studies. In 2009, the *Réseau Rural Français* (French Rural Network) biomass work group [7] adopted a similar approach to agricultural and forest biomass. CARTOFA [3] used and updated these bibliographic reviews, adding a critical analysis of the methods used. The studies conducted in CARTOFA led to the creation of a resource study analysis grid, focusing in particular on forest and agricultural primary biomass, but which could be adapted to any biomass source.

Analysis and summary of the methods used in the studies identified also resulted in the definition of a standard scheme for the availability studies, describing the calculation of availability by successive reduction (*Fig. 4*).

Lastly, by analysing the data used in each study, the best possible use of the existing data could be suggested, as well as the predictable or necessary improvement possibilities, both in terms of selecting the data to be used and the method chosen for their use.

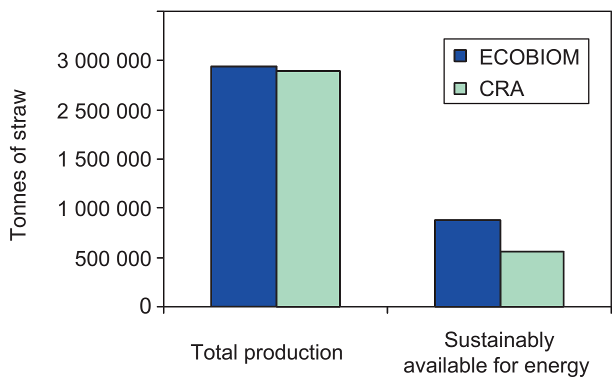

Figure 2

Assessment of the current source of cereal straw available in 2005 for energy in the Champagne-Ardenne according to two studies: ECOBIOM (2009) [1] and CRA [4].

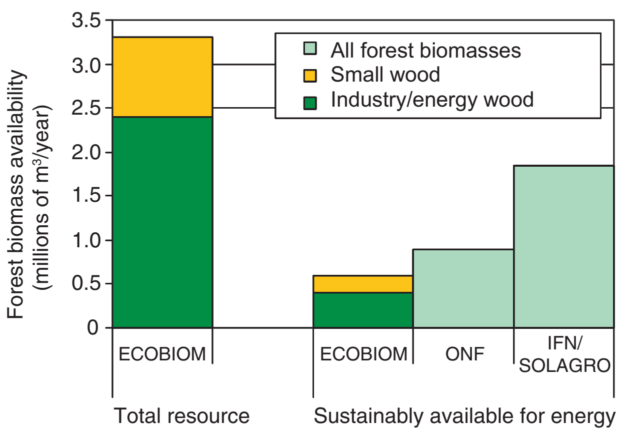

Figure 3

Assessment of the current source of forest biomass available for energy in the Champagne-Ardenne according to three studies: ECOBIOM [1], ONF/CRPF [5] and IFN/SOLAGRO [6].

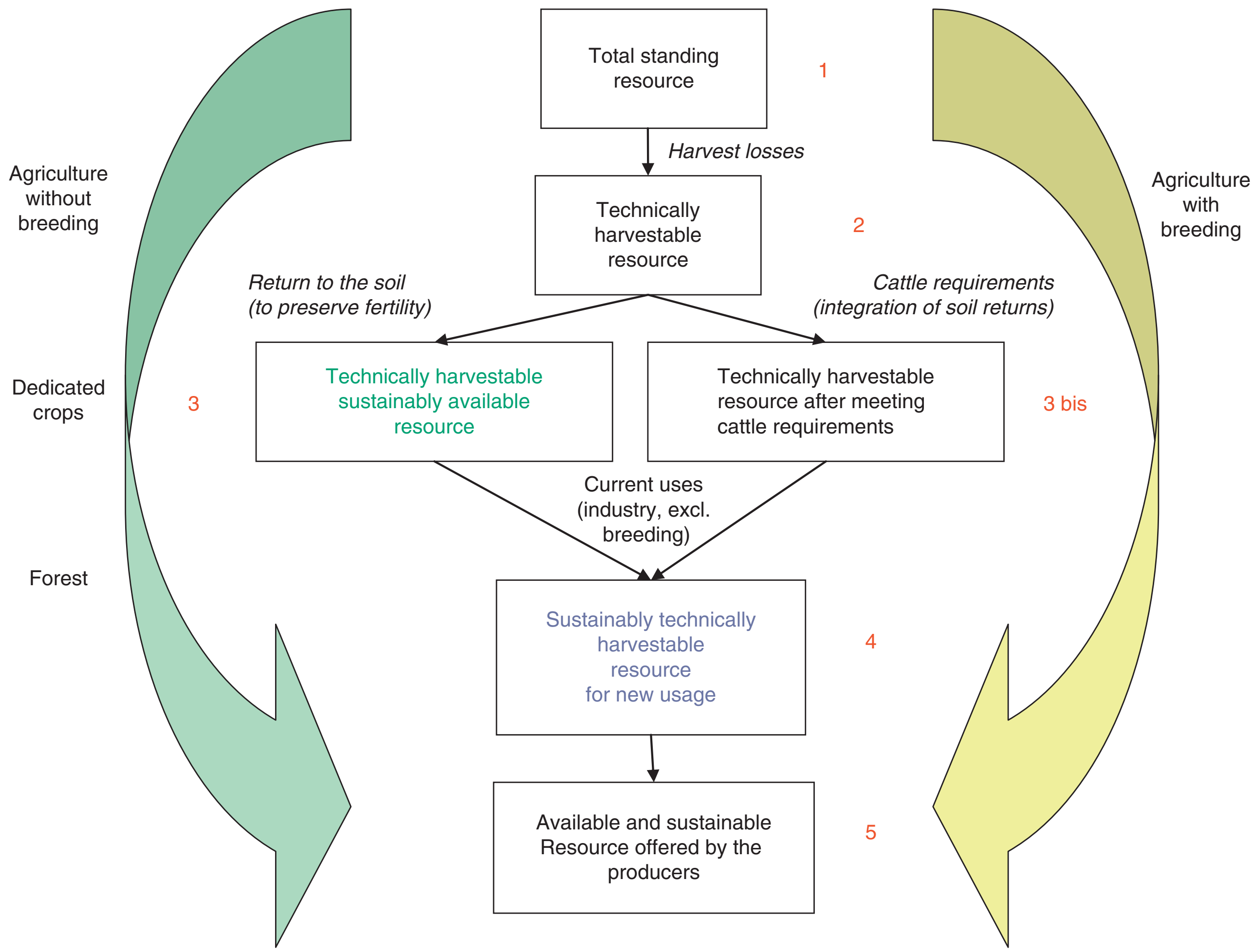

Figure 4

Common methodological scheme for evaluation of biomass primary resources.

2.1 Reading Grid for the Resource Studies

The reading grid defined in CARTOFA [3] identifies four critical points:

- description of the context: general study context: publication date, requester, authors, objectives;
- description of the study scope: geographic area, spatial resolution grid, time horizon, list of biomasses and plant compartments considered, identification of the sources assessed referring to Figure 5;
- description of the methodology used:
  - identification of the main sources of quantitative data, especially statistical, to calculate the total standing source (*e.g.* forest inventory, agricultural areas, crop yields) and to estimate the uses (*e.g.* consumption for heating wood, number of heads of cattle used to calculate cattle straw requirements);
  - sources of parameter values used in the various calculation phases (*e.g.* soil organic matter content, forest scenarios, harvest index or grain/straw ratio, level of losses during mechanical harvesting, etc.);
  - calculation methods used during the main assessment steps, referring to the general diagram (*Fig. 4*);
- splitting and expression of results: spatial grid(s) which may be of several orders successively in a given study (*e.g.* department level – NUTS3 and national aggregation), crops or species, resource categories, units used, etc. This breakdown may differ in the intermediate or final results due to the aggregations sometimes required to move from one step to the next.

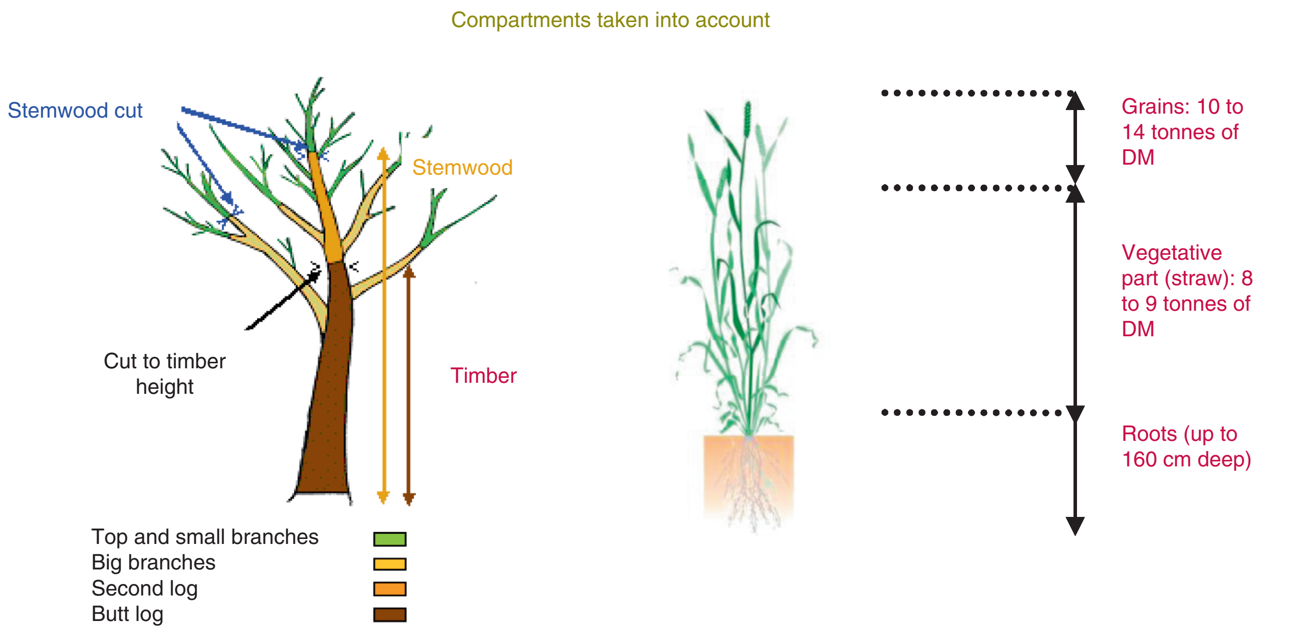

Figure 5

Compartmentalisation of above-ground biomass from trees and crops (*e.g.* straw cereal).

This reading grid was built based on the studies examined in the bibliographic reviews of the CARTOFA project [3], which concerned only agricultural and forest biomass. It can be used for other biomass sources but, in this case, will probably have to be modified slightly or completed. The main objective of this reading grid is to help to identify the main points of each study and of its results in order to determine the advantages and/or limitations and decide those that are comparable. This type of grid can also be used to produce the specifications for a new biomass resource study. Lastly, it can be used to structure a metadatabase holding the studies conduced in France or Europe on this subject.

2.2 Clear Definition of the Compartments Studied

In most cases, forest or agricultural crops are not fully dedicated to the production of biomass which is more a by-product of the main crop (lumber wood, grain, etc.). Sometimes, the objective may be the biomass production, but even under these conditions, the harvesting mode or season may considerably modify the quantity and quality of the biomass extracted: in a forest, the biomass harvested may vary by a factor of 2 depending on whether the logs alone or the whole trees are harvested and, in the first case, the biomass has a very low ash content whereas it may be multiplied by 2 or 3 in the second case.

The definition of the plant compartment taken into account to calculate the biomass source is therefore essential in order to compare the results of various studies. The ECOBIOM project [1] had clearly identified this difficulty of comparing the results of different forest resource studies, simply due to the fact that the tree compartments were not precisely defined.

The following figure (*Fig. 5*) shows a compartmentalisation of trees and annual crops that can be used in the biomass resource studies.

Compartmentalisation of tree biomass is complex. Generally, forest inventories only measure the main stem (stem volume) and the total volume must be calculated with expansion coefficients. Depending on the resource studies, the volume taken into account is the volume of the main stem or the total volume, which is quite different bearing in mind that the volume of the top and the branches may represent 30% to 120% of the stem volume measured by the forest inventory (*IGN* in France). This excludes the stump biomass, generally taken into account in European studies (BEE [8], EUWood [9]), but seldom in French studies, since they are rarely harvested. Lastly, the compartments are defined according to the size and/or average quality of the trees for a maximum economic valorisation. The highest valorisations (*e.g.* sawing) require the most restrictive criteria (large diameter, minimum length). Each compartment can nevertheless be used depending on the market, for a lower quality use; currently, fuel wood is generally the least valorising. Resources are classified by valorisation in order to distribute the availability between the various existing uses and assess the potential use conflicts with new consumers such as green chemistry or energy. The equilibrium in product valorisations between the various uses may therefore be affected by market fluctuations or the appearance of a new use. So even with the highest possible accuracy, compartmentalisation keeps a certain degree of uncertainty that users of the resource study results must keep in mind when using them.

Compartmentalisation of crops is relatively simpler since they are generally grown annually and the main objective is grain. The rest of the crop produced can be dedicated to biomass production (*e.g.* straw).

In case of dedicated agricultural and forest crops, for which the above-ground part is intended for a single use, the physiological stage of the plant when harvested together with its age represent the main information to be provided (impact on productivity and technological quality).

2.3 Multiple and Heterogeneous Mobilised Data

The biomass availability calculation mainly depends on the available data and the means used to process them.

Analysis of forest resource studies is a striking example due to the number of years these studies have been conducted (20 years), and even longer if we consider the forest management plans that use the same calculation principle consisting in planning the forest harvest over the next 20 to 30 years in order to optimise distribution over this period. Forest inventories were first available as paper publications, which made analysis considerably more difficult since data had to be entered on computer, and which also limited the volume of data available. Development of national inventory databases provided access to more detailed and complete data while improving tree compartmentalisation as well as the total availability and technico-economic calculations. Following the change of inventory method by the NFI in 2005, geographic criteria can now be introduced (drinking water catchment perimeter, natural parks, various protection areas, etc.) resulting in constraints on management and calculation of total availability. The quality and accuracy of the estimation have therefore increased progressively over the years and may improve even further with the availability of new data (satellite remote detection, LIDAR, aerial photography) which will allow spatialisation of the resource at the scale of the small forest or even the forest plot. In contrast, the novelty of the non-food industrial outlet for agricultural lignocellulosic biomass accounts for the lack of basic statistical data. In France, for example, even for straw, only limited information is available on production, harvesting and consumption by cattle. It is in fact limited to that collected more or less regularly and exhaustively by the *Bureau Commun des Pailles* (Straw & silage office), created on the initiative of the cereal industry and backed by agricultural entrepreneurs and representatives of the sector. Similarly, unlike grain harvests whose yields are estimated every year by the Statistique Agricole (SSP[(2)]) for each department, no data is available for the yield in straw or dedicated crops, forcing the authors of studies to imagine indirect evaluation methods, thereby increasing the uncertainty on the results.

To determine the resource evaluation methodology, the statistical quantitative databases required for the models have therefore been listed and described, based on a descriptive grid composed of the following ten criteria:

- identification of the producer of the data considered;
- owner of the data;
- subject of the data with a brief description;
- geographic area covered by the data;
- spatial resolution level of the data;
- type of data referring to how it was obtained (*e.g.* inventory of forest stands, survey on the number of heads of cattle);
- processing of the data required so that they can be used in the models (spatial aggregation, updating of old data to a more recent date or to the required date, etc.);
- update frequency;
- data access and availability mode;
- data quality; estimation of the level of uncertainty.

Data availability is highly variable (see metadata tables in Appendix: some data are freely accessible on the Internet with the necessary detail, other data can be obtained *via* specific agreements with the producing organisations, while for other data, a request must be made to extract them from the owner organisation.

Prior processing is generally required before the data can be used in the resource calculation systems:

- aggregation (summing) or disaggregation with a distribution key suitable for the required geographic level;

[2] *Service de la Statistique et de la Prospective* (Agriculture Statistics Office).

- update of old data by combining or not with other data;
- evaluation of missing data (statistical secret or data not collected);
- homogenisation of different data sources (calculation parameters resulting from appraisal or scientific measurements).

2.3.1 Statistical Data Mobilised for the Forest Model

Most data comes from the National Forest Inventory (IFN-IGN). Data can be accessed by annual agreement. Data on the area and volume of standing timber is broken down by forest species, age class and department (NUTS3) or other non-administrative zoning.

The other data required are available either in technical and scientific publications (silvicultural practices), or on the Internet (annual harvest, price of wood, in particular AGRESTE – Ministry of Agriculture).

2.3.2 Statistical Data Mobilised for the Agricultural Model

Two databases are absolutely essential to calculate the resource:
- crop rotations for France are obtained from the ASP(3) available under certain conditions at the scales of the department (NUTS) and the canton. These data, taken from the CAP(4) declarations, are likely to be less accurate due to the simplification of the declarations (split between agricultural subsidies and the type of crops grown) and their access is likely to be restricted in the medium term for data protection reasons;
- data on the grain yield of the major crops most widely found in France are communicated by agricultural statistics (*Statistique Agricole* - AGRESTE). They are used in particular to estimate the biomass yields (straw, new energy crops) by conversion factors determined on the basis of experimental results.

The data used to estimate straw consumption by cattle are obtained from agricultural statistics, whether for the number of heads of cattle (livestock surveys conducted by SSP, RGA(5), BDNI(6), etc.) or for the estimation of straw requirements for each region by animal category (Breeding building survey, Aviculture survey). They are rarely available for the same time period, the required spatial scale and for all animal categories. Several sources and additional information are therefore required (*e.g.* ECUS(7) directory for numbers of horses) in order to create complete data tables.

Soil (BDAT(8)) and weather (*Météo France*) data can be mobilised to calculate the input data for models used to simulate changes in organic matter used to determine straw export coefficients compatible with preserving soil fertility, at small (canton) and circumscribed (a few regions) scales.

Lastly, some calculation system parameters are based on expertise (*e.g.* regional straw export coefficients since modelling is extremely difficult to apply at the scale of the whole of France) and/or bibliography (*e.g.* straw consumption per horse). In all cases, expertise is required for suitable use of raw data.

2.4 Approach by Successive Reductions

Analysis of resource studies conducted in CARTOFA [3] has led to the development of a methodological scheme common to the forest and agricultural resources and availability studies to evaluate the biomass resource (*Fig. 4*). This scheme can be applied without modifying its principle to all biomass sources, both primary and secondary. Some steps can be omitted since not applicable (for example durability for secondary sources).

It is broken down by successive reductions according to the following steps:
- total standing resource (R1): the total biomass of trees and plants potentially mobilizable at the time of the evaluation and before any harvesting operation. This resource is calculated by applying silviculture rules to the forests. These rules stipulate harvesting of variable volumes of wood depending on the species and age of the forest stands. In agriculture, this resource is estimated by applying a yield per hectare of agricultural crop multiplied by the area on the date of the evaluation (*e.g.* for straw: grain yield straw/grain coefficient area of said crop). In this case, we may either consider the total above- and below-ground biomass (stumps and roots in some cases for trees), or a special compartment of the plant (*e.g.* cereal straw);
- technically harvestable resource (R2): the share of the total standing resource which can be taken to the roadside under technical and economic conditions that are acceptable at the time of the evaluation. The difference includes the operating losses: stumps, sawdust, reject, bark and other forest residues; stubble, dust and miscellaneous agricultural residues. Mobilisation techniques vary depending on the local

[3] *Agence de Service et de Paiement*.
[4] Common Agricultural Policy.
[5] *Recensement Général Agricole*.
[6] *Base de Données Nationale d'Identification*.
[7] Directory of key figures for the horse sector produced by the *Observatoire économique et social du cheval de l'Institut français du cheval et de l'équitation (Haras nationaux)*.

[8] *Base de Données des Analyses de Terre*.

conditions and may lead to different loss coefficients for a given type of species considered;

- technically and sustainably available resource (R3): the share of the technically harvestable resource which can be removed without impairing soil fertility and production sustainability. For forests, this is the possibility of harvesting small branches (forest felling residues) rich in mineral elements; for agriculture, this is the straw removals compatible with maintaining an acceptable level of organic matter in the soil. Once again, the pedo-climatic conditions and local practices are determining;
- technically and sustainably available resource after meeting cattle requirements (R3 bis): this step is specific to straw. It is identified separately since harvesting straw for cattle leads to significant modifications in the calculation parameters (straw removal rate, return of liquid manure to the soil). It can be omitted however; in this case, cattle requirements are considered in the next step;
- resource technically and sustainably available for new uses (R4): this quantity is obtained after deducting current biomass uses (including cattle if not carried out in R3 bis);
- resource technically and sustainably available for new uses, offered by the producers (R5): it is obtained by subtracting from the previous balance the quantities not placed on the market since producers (farmers or forestry operators) do not wish to. There are numerous reasons behind this socio-economic refusal to sell (price, no need for cash, patrimonial management, disagreement with the technical principles determining the source to be mobilizable, etc.).

While the evaluations of resources R1, R2, R3, R3 bis and R4 can be defined objectively and calculated using robust methods and parameters, evaluation of resource R5 is still poorly modelled due to the human factor to be taken into account and criteria that are often not expressed, poorly defined or not quantified and which play a role in the decision of the producer (or more precisely the owner in case of forests) to sell his resource. However, it may – or even must – be taken into account when conducting procurement studies in the advanced phases of industrial projects, since experience has shown that this human factor may significantly reduce the resource finally mobilizable.

Remark: all calculations are made in native units (m^3 or tonne, with a specific moisture content) in order to retain maximum accuracy throughout the calculation chain for the various biomasses. The quantities are eventually converted into one unit in order to add together the various biomass resources, the unit varying depending on the study objective (energy, heating or electrical, biofuels, etc.).

2.5 From Method to Application: Major Operational Stakes

The total production of standing biomass, under current conditions, may appear very large, and therefore attractive, at the scale of a country like France, as illustrated by Figure 6.

However, significant reductions may be made on the total resource from one step to the next during subsequent phases of the evaluation (*Fig. 6*). The evaluation carried out in CARTOFA leads to a zero (and even negative) straw resource for R4. There still seems to be considerable forest biomass, but the last reduction to obtain R5 could not be carried out (no data on whether the forest owners were prepared to sell). We must therefore

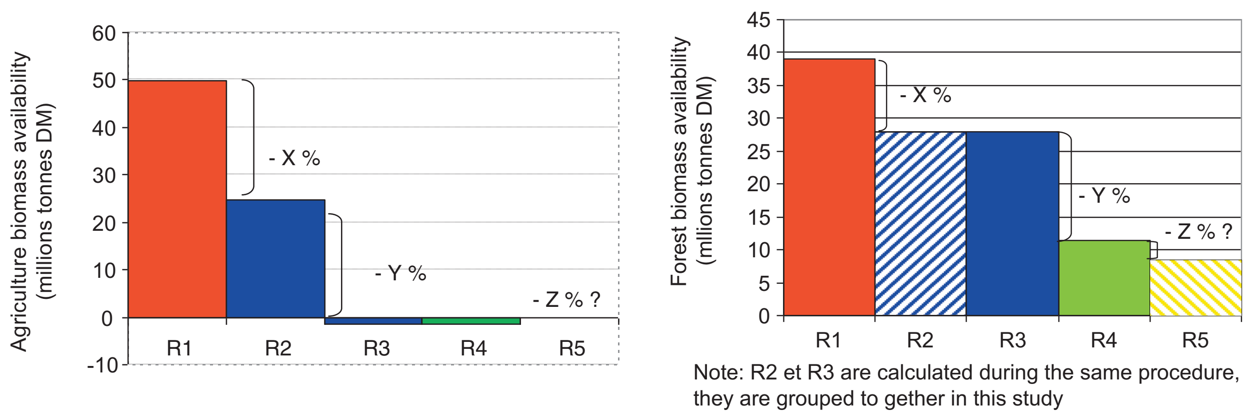

Figure 6

Evaluation of the current ($t = 2010$) agricultural (cereal and corn straw) and forest biomass in the successive steps of the method developed in CARTOFA [3].

TABLE 1

Summary of the results of three national studies on the forest biomass resource in France (millions of tonnes of dry matter)

	R1	R3	R4
Ginisty *et al.* [10]	38.0	33.0	18.4
Colin *et al.* [11]		22.6	7.9
CARTOFA [3]	37.5	27.0	12.4

make sure not to take the results of R4 as being biomass directly available for new uses. This biomass is in fact technically and economically mobilizable, but significant incentives will probably have to be applied on the owners to convince them to market this forest biomass.

In addition, these results suggest the potential sensitivity of this exercise to the methodological options (including the choice of input data) and highlight the operational stakes in terms of procurement which are inevitably related.

While the results R1 both in agriculture and forestry is relatively homogeneous from one study to another (same data sources, similar production assumptions), significant variations are observed when estimating R2 or R3 and even greater variations in the next ones. This point can be illustrated by various examples. In 2009, two national studies [10, 11] evaluated the ligneous biomass availability. CARTOFA [3] conducted a new evaluation in 2012. Table 1 summarises the results of these various studies.

For the three studies, the similar data, parameters and methods lead to very similar results for R1. Source R3, however, was calculated differently:

- Ginisty *et al.* [10]: reduction on R1 by applying exploitability rates defined by experts on the resource exploitability classes;
- Colin *et al.* [11]: according to the calculation of economic balance of forest exploitation, only plots with a positive operating financial balance can be considered for R2 and R3. The operating cost varies depending on the stand types and the 4 exploitability classes defined by exploitability criteria (slope, forwarding distance, etc.);
- CARTOFA [3]: same method as in the study conducted by Colin et *al.*, but using more detailed exploitability data: in this case, the operating cost varies directly depending on the exploitability criteria and no longer depending on the classes synthesising these criteria. This avoids threshold effects penalising the financial balance of forest exploitation for some plots, especially in mountainous regions.

In view of the variation in the results between the different studies, it is important to carefully examine the data, methods and assumptions chosen in order to draw suitable conclusions. It is also essential to check whether or not the studies include the reduction required to take into account the readiness to market of the resource owners, which are often not production-oriented. The above-mentioned studies do not include this dimension.

In agriculture, the differences when estimating the animal headcounts and their requirements have led to a considerable increase in the estimation of cattle straw requirements between the previous studies and the estimation conducted in CARTOFA. In addition, it would appear that experts tend to overestimate the requirements for straw return to the soil compared with the estimation of these requirements obtained by applying the AMG model (from the names of its authors Andriulo, Mary, Guerif) on the evolution of soil organic matter. The two methods were tested in the Centre region as part of the CARTOFA project.

3 THE SECTOR ACTIONS, KNOWLEDGE STILL TO BE ACQUIRED

The sector actions concern the evaluations along the entire chain: from production of the resource through to end use of the product. The aim is to assess the global impact of an activity: environment, economic, social and risk dimensions. Multicriteria evaluation methods meeting the characteristics of the sectors studied must therefore be used. A specific methodology approach must be adopted so that the evaluations are as reliable as possible. Life Cycle Assessments (LCA) are partially involved in the multicriteria evaluation since they focus on some of the criteria concerned. The discussions which have taken place on the first-generation biofuel LCAs have demonstrated the true value of the method. Certain research projects have therefore been initiated, firstly to obtain this solid methodological base and secondly to extend the evaluation criteria to other dimensions of interest for both private and public decision-makers. Two successive ANR projects, ANABIO [12] and BIOMAP [13], have tackled this subject.

As with the biomass resource availability studies, in ANABIO/BIOMAP, the method had to be developed to compare the evaluations of the different biomass sources. Although LCA was chosen as the basis for the multicriteria method, specific studies had to be conducted on the other criteria. The methodological studies of a European project focusing solely on the forest and wood, EFORWOOD [14], can be compared, since the conclusions agree:

– the socio-economic criteria are difficult to calibrate;
– since there is insufficient data, expert data and assumptions must be used, making the evaluations fragile and especially non-reproducible.

However, these studies lead to the creation of a process, a series of steps which form an initial framework for the evaluation.

The issues set-up by the LCA have not all been solved, and evaluations are still required, especially on primary biomass: land use and change of land use, carbon sequestration, water requirements, impacts on biodiversity. Note that this observation is shared by many other types of resource and sector, opening a broad field of investigation which will probably take time to elucidate.

Overall, in order to obtain sector analyses that can act as decision-making tools, other methods could be implemented or even adapted to the biomass conversion sectors, irrespective of their use. One of the challenges would be not only to have suitable evaluation methods for each use, but eventually be able to include their interrelations.

4 PROSPECTIVE STUDIES, VARIED OBJECTIVES AND METHODS

Resource studies aim at determining the quantity of biomass: what is the available quantity under the current crop rotation conditions, according to the current state of the forest, with the current harvesting methods or under the present economic conditions and with the current uses and consumption? These factors are all likely to change over time and today's biomass availability and uses will not be those of tomorrow or the day after.

The public authorities, to define a renewable energy development programme (PNER and others) or companies deciding to build an energy production plant, all want to know the future availability, the location, and at what price it can be mobilised. Prospective studies answer these questions in various ways depending on the context. Three approaches can be outlined.

4.1 Approach 1: Case Studies

The aim of the availability studies carried out when installing an industrial site (*e.g.* BTL[9] production) is to determine whether the biomass availability will be sufficient to meet the requirements of the industrial site under satisfactory technico-economic conditions. The resource study therefore defines the supply in required biomasses (forest wood, by-products of the wood industry, wood at end of life, straw, etc.) at the time scale considered (present, 10 or 20 years horizon) in the perimeter that it seems reasonable to prospect in order to limit transport costs. The socio-economic context is then analysed to determine the ability of the actors (owners, farmers, forestry operators, cooperatives, road, rail and waterway transport companies) to mobilise and transport the biomass to the conversion site. Lastly, current competition for the use of this biomass and its future trend are analysed to check that the calculated availability can be accessed without excessive competition.

This type of prospective study therefore focuses on an industrial project and the aspects of availability, competition with other uses, mobilisation and transport costs are critical, but often limited to a relatively restricted geographic perimeter.

The resolution scale is often small, allowing the logistics costs to be calculated more precisely. The future supply is generally calculated according to a *"business as usual"* trend. Future biomass availability therefore appears as a figure (although derived from various assumptions) which is not to be fundamentally changed. In addition, the flows entering and leaving the area may be taken into account more or less precisely in the analysis.

4.2 Approach 2: National or European Objectives Reached or Not

Studies conducted at national or even supranational scale (*e.g.* European Union) are designed to provide a framework and the competition aspects may be less important. For example, the aim of the CARTOFA project in its 2020 prospective study was to determine the equilibrium conditions between supply and demand in France by this date.

Based on the estimation of the current biomass supply, assumptions were made on the trend in parameters to estimate the biomass offer in 2020. Climatic change was taken into account through its effect on the crops yields as simulated by the Climator study [15]. This supply was then compared with the biomass use objectives for energy (heating, electricity and transport) set by the PNER at this date. The study results showed a supply deficit of more than 15 million tonnes of dry matter,

[9] Biomass to liquid.

for a total demand of 55 million tonnes. The supply therefore had to be significantly increased in order to meet the demand. Two levers were considered:

- change the crop rotations to introduce a proportion of crops dedicated to the production of energy biomass (*e.g*. introduction of the whole plant triticale instead of a grain cereal);
- change the economic context of the wood sector (*e.g*. increase the price of wood at forest road side) to allow exploitation of forest plots more difficult to access and currently too expensive to operate.

Several scenarios have been considered to ensure that supply meets demand: use a single lever (agricultural supply or forest supply) or combine the two. It turns out that using a single lever is insufficient (the forest alone cannot supply the extra 15 million tonnes of dry matter) or considerably disturbs the French cereal export markets. In contrast, the PNER objectives can be reached by simultaneously using the two levers considered, while preserving the most strategic cereal export markets (UE28 and Mediterranean basin) and sustainably using the forest potentials.

The prospective study conducted in CARTOFA therefore operates by comparing the biomass supply calculated at a future date with a demand predicted or estimated by the PNER. The balance between supply and demand is achieved on the basis of supply trend scenarios. By analysing the consequences of these scenarios on agricultural and forest production, we can assess the feasibility of meeting the biomass demand for each scenario and, finally, decide whether the public objectives can be reached and under what conditions.

4.3 Approach 3: Biomass in the Energy Mix

A third type of analysis on meeting the biomass demand was conducted in the VALERBIO [16] project. In this project, the aim was to analyse, for various demand levels, the effects of competition between different energy sectors consuming biomass. Prices are exogenous data.

With this approach, as with the previous ones, the first task was to determine the supply in agricultural and forest biomasses capable of meeting the requirements of the various energy processes considered (production of heat alone, electricity and heat cogeneration, first or second generation biofuels). The calculation concerned:

- the quantities produced at different dates (as with CARTOFA), taking into account the trend in forest stands, crop rotations and grain yields for agriculture,
- the demand for traditional uses (food, cattle, wood industries) through five demand trend scenarios including both the trends in quantities available and their market prices.

Three renewable energy demand scenarios have been defined for the 2050 horizon based on the PNER objectives for 2020, each scenario defining demand levels and a breakdown between the various energies.

A calculation to optimise the economic allocation of the resource of the various biomasses to different industrial processes (first generation *versus* second generation fuels, ethanol *versus* BTL) or energy sectors (heating energy *versus* biofuels) taking into account the material yields and the production costs has been carried out. The calculation results show that the biomass availability estimated as part of this project could meet a demand of 30 millions toe[10] (70 million tonnes of dry matter), exceeding the PNER 2020 objectives set at 20 million toe, but could not improve on this figure without massive use of imports.

The model can be used to define the optimum technological mix meeting the respective demands for heat alone, cogeneration and biofuels at the lowest total updated cost, based on the biomass resource supply. The results show the importance firstly of the distribution of the various biomass quantities and secondly of the demand scenarios, *i.e*. the demand level and type of energy demanded.

This type of prospective study is an extremely interesting approach to estimate the allocation of biomass between the various energy uses. It could be developed further by adding a smaller geographic dimension (*e.g*. local biomass availability, including transport distances and costs for various industrial sites), highlighting the synergies or competition with other types of industrial use, but also the global energy balance of a given sector.

4.4 Balance

While prospective analyses are far from being absent from "biomass" resource and procurement studies, they are faced with numerous supply and demand assumptions and therefore require a certain degree of simplification in order to remain understandable. The three types of prospective study each meet a particular requirement for a cost/satisfaction ratio acceptable. The first approach could satisfy the company and the second the public authority which wants to check its renewable energy policy framework. The approach adopted in VALERBIO [16], certainly the most elaborated and the most promising, is also the most difficult to implement and involves a significant amount of data on the sources as well as on the costs of various sectors. The development of databases storing this type of parameter

[10] Tonne oil equivalent.

could answer the questions, more directly operational, raised by decision-makers.

CONCLUSION

The supply of biomass to the bioenergy sectors is a key but complex issue.

Evaluation of quantities, an essential starting point to investigate the other aspects, is now reaching a level of maturity where the successive estimations made are tending to converge and can act as reference. This is the case in particular of forest resource estimations, which date back for many years. Agricultural resource estimations are making significant progress, although they have not yet reached a comparable degree of maturity. We must nevertheless:

– make sure that these estimations remain transparent in order to compare them, create metadatabases to store the studies and acquire databases of results to build available biomass repositories;
– reconcile the national evaluations with the European studies often conducted by third-party country organisations which do not have the same diversity of crops, practices and biomass types as France;
– continue methodological research studies and pooling of approaches.

For the resource studies, the methodological evolutions aim firstly at improving the resource spatialisation required to answer issues of transport and cost delivered to the conversion site and, secondly, deal with the socio-economic aspects persuading a biomass producer/owner to sell its products and choose one market rather than another or even to take up production (case of dedicated crops). In addition, for a certain number of resources, the evaluation exercise highlights the lack of knowledge and/or of technical references (*e.g*. productivity, cost, collection of dedicated crops) as well as, in some cases, the complete absence or lack of statistical data (*e.g*. consumption of straw by cattle). R&D studies must be conducted and the national statistical departments (NUTS3) must take into account these new productions/uses in order to reduce uncertainties at all levels and improve the accuracy of the resource studies.

For the prospective studies, apart from simply projecting assumptions of the current supply in the more or less long term, methodologies including development of the bioenergy sectors as well as evolution of the other sectors producing and converting the same resource must be developed. This involves formulating scenarios predicting the evolution of society, then translating these assumptions into scenarios for land use, production of raw material including biomass and its use by the various sectors.

Study of the sectors (not just the bioenergy sectors) then appears as an essential complement to allow the prospective studies to take into account the complex interactions between the various stakes impacting the use of biomass.

The biomass resource study can no longer be considered as a subject isolated from its societal context. On the contrary, it must be included in a global approach based on changing requirements in terms of food, raw material and energy, in a context of sustainability and preservation of the environment. The next step is to conduct studies that simultaneously including the three axes (resource, sector and prospective study) in a system approach must therefore be conducted.

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APPENDIX : LIST OF METADATA REQUIRED TO APPLY THE SOURCE EVALUATION METHOD PROPOSED BY THE GIE ARVALIS/ONIDOL IN THE CARTOFA PROJECT

Data producer	Owner	Subject	Geographic area covered	Resolution	Data type	Update frequency	Access mode	Data quality[1]
SSP	MAAP	Cattle headcount	France	Canton	Census	10-year	Public and free	Very good
SSP	MAAP	Animal headcounts	France	Region	Statistical survey	2-3 years between RGA	Public and free	Average to good
SSP	MAAP	Cattle headcount	France	Departmental or regional depending on the cattle density	Census on sample of farms greater than a given size	Annual	Public and free	Average to very good (in department with high cattle density)
EDE (Chambers of agriculture)	MAAP (DGAL)	Cattle headcounts	France	Department (NUTS3)	Identification by chip	Six-monthly	Public upon request	Very good
Haras Nationaux	Haras Nationaux	Horse headcount	France	Region	Compilation of SSP surveys and identification by chip	Annual	Paying upon request	Average to good (to be confirmed)
SSP	MAAP	Breeding installations and conditions	France	Department to region	Statistical survey	7 to 8 years (2010)	Limited to data processed upon request and publications	Good to very good in the breeding departments
SSP	MAAP	Equipment and buildings of poultry farmers	France	Department (NUTS3)	Survey on statistical sample completed by simplified survey extended to all farms with a minimum number of poultry	4 years	Restricted	Very good despite small farms not being taken into account

(1) Quality mainly expressing an evaluation of the level of uncertainty by the authors.

APPENDIX *(continued)*

Data producer	Owner	Subject	Geographic area covered	Resolution	Data type	Update frequency	Access mode	Data quality[1]
MAAP/AUP/ France Agrimer	MAAP	Crop rotation	France	Communal / Cantonal	Crop rotation declaration by farmers	Annual	Agreement	Very good
SSP	MAAP	Crop yield	France	Department (NUTS3)	Exhaustive survey on production and harvest	Annual	Public Web	Very good
Analysis laboratories	INRA and laboratories	Analysis of agricultural soils	France	Canton	Soil analysis result	Annual Series of 5 years	Public / Web	Very good
Météo France	Météo France	Climatology	France	Small region	Average measurements	Annual	Agreement	Very good
Inventaire Forestier Français	Inventaire Forestier National (National Forest Inventory)	Inventory of all mainland France forests, stands and hedges	France	All. Potentially 1 km^2	Land measurements on systematic sample	Annual	Agreement purchase	Excellent. Accuracy depends on number of points
Enquête Annuelle de Branche Exploitation Forestière et Scierie (Annual Branch Survey of Logging and Sawmill)	SSP	Forest harvest and production of French sawmills	France	Department	Survey	Annual	Public	Declarative
Survey on energy consumption by households (part of the housing study)	MEDEM	Energy consumption by households	France	National Administrative region	Statistical survey	Five-year, Annual update based on more restricted panel	Public	Average Declarative

(continued)

APPENDIX *(continued)*

Data producer	Owner	Subject	Geographic area covered	Resolution	Data type	Update frequency	Access mode	Data quality[(1)]
Observatoire économique de la filière bois (Economic observatory of timber)	Office National des Forêts (ONF) / Experts / Union des Coopératives Forestières Françaises (*UCFF*) published by *France Bois Forêt* (FBF)	Price of standing timber (ONF) Price of timber at roadside Price of timber delivered (UCFF)	France	France	Index	Quarterly	Public	Good
Observatoire économique de la forêt (economic observatory for forest) Lorraine	ONF / Experts / UCFF published by DRAAF Lorraine	Price of standing timber Price of timber at roadside	Lorraine	Lorraine	Index	Quarterly	Public	Good
Price of standing timber in pubic forests	ONF	Price of standing timber in ONF public sales	France	France	Average values	Annual	Public	Good
Results of standing timber sales	FORDAQ	Result by timber lot of the selling price (by species and unit volume)	France, but mainly regions in the northern half	Regions	Values	Daily	Subscriptions	Variable
Survey on the final value of forest operation products	MAAP	Price of timber at roadside	France	France	Average values	Annual last survey in 2009	Public	Average