Prospects for Farmers' Support: Advisory Services in European AKIS
WP 4 – AKIS ON THE GROUND FOCUSING KNOWLEDGE FLOWS SYSTEM | Topic 2

The capability of advisory services to bridge research and knowledge needs of farmers

The role of Decision Support Tools (DSTs) in the French context

Pierre LABARTHE
Damien DEVILLE

National Institute of Agricultural Research (INRA)

France
October, 2014

This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement nº 311994

Please reference this report as follows:

Labarthe, P.; Deville, D.; (2014): The capability of extension and advisory services to bridge research and knowledge needs of farmers. The role of Decision Support Tools (DCTs) in the French context. Report for the AKIS inventory (WP4 - Topic 2) of the PRO AKIS project. Online resource: www.proakis.eu/publicationsandevents/pubs

Content

1 Executive Summary 5

2 Introduction 6

3 Selecting and delimiting the case-study 8

4 General description of the case study 10

4.1 The *Phytnes* DST 10

4.2 The *Farmstar* DST 11

4.3 The *Di@gnoplant* DST 11

5 Methods, data collection, and stakeholder involvement 13

6 Results 14

6.1 Actors and sources of knowledge 14

Main sources of knowledge and main knowledge flows in the three cases 14

Summary of preliminary findings: knowledge sources and knowledge flows in the context of DSTs 17

6.2 Content of the knowledge exchanged and processes supporting these exchanges 18

Towards a standardisation of knowledge flows within AKIS? 19

Towards a formalization of the partnership within AKIS 20

The integration of farmers' needs still under question 21

Summary of preliminary findings about content and methods of knowledge exchanges in the context of DST 22

6.3 The role of advisory services vis-à-vis DSTs development 23

7 Discuss and assess the performance of the knowledge flows and identify best-fit practices for advisory services 26

8 Conclusions 27

9 References 30

10 Appendices 32

10.1 Appendix 1. Additional information about methodology 32

10.2 Appendix 2. Presentation of the three DSTs 34

10.2.1 Description of *FARMSTAR* 34

10.2.2 Description of *Di@gnoplant* 36

10.2.2 Description of *Phytnes* 37

List of figures

Figure 1 What relations between DST and advisory services in AKIS. A theoretical perspective. (source: the authors) 8
Figure 2 The Knowledge flows in the FARMSTAR case (source: the authors) 15
Figure 3 The knowledge flows in the Phytnes case (source: the authors) 16
Figure 4 The knowledge flows in the Di@gnoplant case (source: the authors) 17
Figure 5. From satellite to field: the different steps of the FARMSTAR DST (source: ARVALIS) 34
Figure 6. Example of FARMSTAR interface with a nitrogen map (source: Arvalis) 35
Figure 7. National diffusion of FARMSTAR in 2013 (source: ARVALIS) 35
Figure 8. Examples of the pest picture library of Di@gnoplant (source : the authors) 36

List of tables

Table 1 Distribution of French main OAD according to the type of research partner involved and to the role of advisory services (source: the authors) 12
Table 2 What role for farm advice in the empirical validation of the DST in the Farmstar case (source: the authors) 24
Table 3 What role for advice in the empirical validation of the DST (the Phytnes case) (source: the authors) 24
Table 4 What role for farm advice in the empirical validation of the DST in the Di@gnoplant case (source: the authors) 25
Table 5. List of people interviewed (source: the authors) 32

1 Executive Summary

This report is part of Work Package (WP) 4 of the PRO AKIS project. This WP explores the contribution of farm advisory services to new knowledge flows within the agricultural sector. It is based on a case study methodology. This report is part of 'topic 2' of WP4, which deals with the relations between research and practice, in the context of changing roles of public and private actors within national Agricultural Knowledge and Information Systems (AKIS). More specifically, we want to highlight the specific role of advisory services in these relations.

This report focuses on the role of Decision Support Tools (DSTs) in the new relations between research and farmers. DSTs are numeric devices, based on Information and Communication Technologies (ICTs). They provide farmers with new interfaces to access scientific knowledge about the agronomic management of their farm. This could be software, smartphone applications, satellite technologies linked to precision farming, etc. We want to better understand the role and consequences of such DSTs on the knowledge flows within the agricultural sector, and on the role of advisory services regarding these flows. Are advisory services bypassed by DSTs or do advisory services still have a role to play for integrating and validating the knowledge flows generated by DSTs?

The analysis is based on three DSTs in the French agricultural sector: a smartphone application enabling the identification of pests for horticultural production (Di@gnoplant, created by INRA, a public research institute), numeric maps derived from satellite technology to support precision farming for nitrogen fertilisation (Farmstar, created by Airbus Industry and ARVALIS, an applied research institute), and software standardising all the data base needed by farm advisors (Phytnes, created by a union of French farmers' cooperatives). The qualitative analysis is supported by interviews with the main stakeholders involved in the conception and diffusion of these DSTs (advisors, researchers, engineers and c.o. of private companies, etc.). The report presents the three case studies in detail, as well as diagrams representing the knowledge flows associated to the development of each DST. It highlights two main changes induced by DST regarding knowledge flows in French AKIS: i) a growing codification and standardization of the knowledge exchanged between the actors, and ii) a formalisation of the relations between them. There are more and more contracts between actors, where advisory services tend to become "clients" of DST sold by research organisations, either public or private ones.

With regard to the role of advisory services, we began the investigation with the hypothesis that DSTs would mostly affect the front-office dimension of service. As DSTs are interfaces that connect directly research and farmers, they could theoretically "bypass" advisory services. However, this does not seem to be the case. DSTs are new cognitive resources for the farmer-adviser service relationship, and such a relationship seems still to be needed to integrate heterogeneous knowledge and support farmers' decision. Nevertheless, DSTs could have a great impact on the back-office R&D dimension of advisory services. In our cases, DSTs tend to downsize the role of farm advice in the production of evidence supporting knowledge flows between research and practice. Under certain circumstances (such as the involvement of big private companies), this may lead to situations of growing asymmetries of knowledge within the AKIS, to the detriment of farm advisory services.

2 Introduction

Agricultural advisory services[1] are now clearly acknowledged to play a major role in supporting farmers in a transition towards more sustainable practices, including in the reduction of their use of chemical inputs (pesticides, fertilizers, etc.). This is true both in the academic sphere (Cowan and Gunby 1996, Wilson and Tisdell 2000, Vanloqueren and Barret 2008), and in the political one. New tools of the European agri-environmental regulation explicitly target famers' access to knowledge. Some of the instruments target the individual level, such as the "Farm Advisory System" (Regulation (EC) N° 73/2009). This regulation aims at providing farmers with the information they need to adapt their practices to the requirements of the environmental and sanitary standards of the Common Agricultural Policies (CAP). Other policy instruments target a more global level: the level of the Agricultural Knowledge and Information System (AKIS). This is for instance the case of the European Innovation Partnerships (EIP), which aims to enhance the relations between different organisations of the systems: farmers and farmers' organisations, research institutes and universities, SMEs, knowledge brokers and advisory organisations. The assumption of such policy instruments is that the dynamics of innovations will increase with the levels of knowledge flows between the various actors of the AKIS. Nevertheless, these knowledge flows are hard to capture and describe, especially in a context of increased pluralism of the actors of AKIS (for instance in the sector of farm advisory services, as it was highlighted in the PROAKIS inventory / WP3 of the project).

The overall objective of the Work Package (WP) 4 of the PRO AKIS project is to comparatively explore and describe selected forms of advisory services and agricultural knowledge flows in Europe, accounting for the diversity on the supply and demand conditions across different countries/regions and diverse types of farmers. More specifically, topic 2 of WP4 seeks to describe the roles, the opportunities and the limits of extension and advisory services to fulfil the bridge function between farmers and research especially with regard to farmers' provision of public goods and ecosystem services and to their capacities to respond to global challenges. Hereby, the different institutional settings of advisory services (Governmental, privatised, mixed, commodity-based, client-based extension, among others) are explicitly taken into account.

One of the major transformations in the relations between farmers and research in Europe is related to the opportunities opened by Information and Communication Technologies (ICTs) (Poppe et al. 2013). These innovations have led to the development of new Decision Support Tools (DSTs) for farmers. This DST (*Outils d'Aides à la Décision*-OAD in French) are defined as follows in the French context of pest control management: "*OAD are tools that describe plant health situations about the presence, development and forecast of pests and that can integrate decision rules to guide the OAD about whether to intervene or not*". The integration of environment is a new challenge for the development of these tools.

<u>The goal of the case study</u> presented in the report is to explore how DSTs can transform the contribution of advisory services in bridging research and practice in the agricultural sector. Such innovations have a great potential for enhancing these connections:

[1] Farm Advisory Services can be defined as "the entire set of organizations that will enable the farmers to co-produce farm-level solutions by establishing service relationships with advisers so as to produce knowledge and enhance skills" (Labarthe et al. 2013, p. 10).

- i) The willingness to control and guarantee food safety and to protect the environment has induced many initiatives (both public and private), seeking the traceability of farm practices and their effects. This leads to the production of many data and data bases, which can be used in scientific modelling of the impact of agriculture on environment.
- ii) The knowledge accumulated by agronomic research has resulted in many available models to represent the possible consequences of diverse agronomic techniques on the ecological and economic performance of farms.
- iii) New technological devices (software, smartphones, laptops, satellite technologies and GPS, precision farming equipment, etc.) and ICTs open a range of opportunities to convert such models into DSTs that can be used directly by farmers and/or advisors, initiating new channels to access information and knowledge, new time frames for this access, and thus new opportunities for bridging research and farmers.

However, the development of these technologies is also associated to new economic models, in a context of moving boundaries in the respective roles of public and private actors in European AKIS. DST may be developed and sold to farmers by private service firms (sometimes not related to the agricultural sector), or produced by traditional actors of AKIS, or embedded in new public-private partnerships (Labarthe et al. 2013). In such new institutional configurations, traditional farm advisory services can be excluded, associated, or included to the conception and development of the DSTs. **Our main research question is thus to understand whether farm advisory services still have a role to play in the new knowledge flows between research and practice induced by DSTs within AKIS**. And if so, which role? **In that respect, we will investigate more specifically whether farm advisory services allow** (figure 1):

- **a better integration of farmers' needs in the interactions between research and farmers** based on DSTs, mostly in the front-office dimension[2] of the services?
- **a better validation of the knowledge and evidence embedded in the DSTs,** mostly in the back-office[2] dimension of the services?

The report is organised as follows: after explaining how the cases were selected and delimited (section 3), we provide a brief description of these cases (section 4), as well as of the methodology applied to collect empirical data (section 5). The results presented in section 6 and discussed in section 7 explore different dimensions of the cases: i) actors and sources of knowledge (including diagrams of the knowledge flows); ii) content, processes and methods of knowledge exchange; iii) and the specific contribution of farm advisory services to the new knowledge flows induced by DSTs.

[2] The time that advisers dedicate to direct interactions with farmers (also called "front-office") is supposed to better integrate farmers' needs in the search for new solutions. But the quality of services also depends on how advisers update the knowledge and information that they use in advice, though activities and tasks known as "back-office" activities, and which include "training, R&D, experiments, training, construction of data base…" (Labarthe and Laurent, 2011).

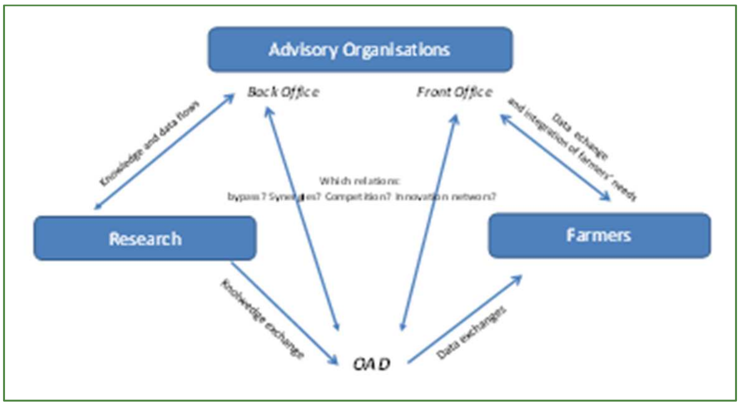


Figure 1 What relations between DST and advisory services in AKIS. A theoretical perspective. *(source: the authors)*

3 Selecting and delimiting the case-study

The aim of this section is i) to specify **the criteria used to select the case-study** presented in this report; and to ii) explain how it relates to the transformations of advisory services and AKIS in France as described in the WP3 of the PRO AKIS project (Labarthe 2014).

As previously mentioned, there has been a boom in the production of DSTs for farmers, resulting in an emerging market in the French agricultural sector. A recent (non-comprehensive) study identified more than 140 OAD in France, already on the market or being developed (FNLON 2009). Nevertheless, there is a wide diversity in the aim[3], history and diffusion of these tools. Some are the result of research projects and follow academic objectives. Others are developed by firms that look for new service market development in the agricultural sector. These firms sometimes come from outside the agricultural sector: service companies, firms using satellite technologies, etc.

A first criterion of selection of the cases is related to their stage of development. We wanted DSTs that:

- are already diffused and available for farmers;
- integrate innovations based on technologies coming from outside of the agricultural sector (ICTs, satellites, etc.);
- aim at combining farmers' objectives (about the economic performance of their farm) with environmental and sanitary objectives (such as pesticides or fertilizers reduction).

Our aim is also to explore how DSTs are integrated in new institutional arrangements that reshape the boundaries between public, private, and third sector organisations. Ideally the cases at stake integrate some of the **main trends characterizing the transformation of French AKIS and advisory services at national level in France** (Labarthe 2013). This includes:

[3] Some of them aim to provide diagnostics and evaluate the risks of contamination by pests (based on reference data bases, or on more complex mathematical modelling including knowledge about climate, plant biology and ecology, pest diffusion, etc). Others go one step further and act as decision support, including evaluations of the risks and of the economic and agronomic performance for farmers when they adopt the practices recommended by the scientific modelling supporting the DST.

- *An increased pluralism of actors*, characterized by the stronger role played by third sector organisations, mainly farmers' cooperatives. Some of these cooperatives are, for instance, members of a union (In-Vivo[4]) that have become a major actor of the sector. Today, this union has a very important R&D unit. We wanted our case to integrate the role of this union of cooperatives in the relations between research and practice in French agriculture.
- *The development of new public-private partnerships* to support innovation in the agricultural sector. The long history of cooperation between the traditional actors of AKIS (research institutes, applied research institutes, chambers of agriculture, etc.) is challenged by new initiatives supporting a project dynamic between private actors and public research (Labarthe et al. 2013).
- *The willingness of new actors to develop and sell new solutions,* and DSTs, for farmers, based on new technologies. Such solutions may at times bypass advisory services, as new actors enter this market. This includes service firms, upstream and downstream industries, but also public research institutes, who receive more and more incentives to develop services for farmers.

In order to capture these different trends, we built a matrix that enables the classification of the major DSTs available in France according to two dimensions (see table 1):

- i) **The type of research organisations involved** in the development of the DST. We chose to make a distinction between four categories :
    - **Public research**: this includes universities and public research institutes, and mainly the National Institute for Agricultural Research (INRA) that has developed software or smartphones applications for farmers and advisers, so as to increase its impact on practice.
    - **Private research**: this includes the R&D departments of private companies, mainly from upstream industry (chemical, fertilisers, etc.) and from the service industry (ICTs, software, etc). These firms propose new services to farmers, either as their core business, or as a way to support the commercialization of inputs to farmers.
    - **Third sector (farmer based organisations)**: this is, for example, the case of the union of cooperatives InVIVO, whose R&D unit aims to support the development of new services by cooperatives.
    - **Public-private network**: in this case, the sources of knowledge on the research side come as a joint initiative between a public research organisation and a private company.

- ii) **The integration (or exclusion) of advisory organisations in the innovation networks** created to support the development and diffusion of the DST. We have found three different situations, where advice is:
    - **Integrated**: advisory organisations were fully active in the development of the DST. Such DSTs can be designed either for the advisor only or for being integrated in the interactions between farmers and advisors (and sometime sold to farmers).
    - **Associated**: as for 'integrated' cases, the DST may target either the relations of advisors with farmers (front-office) or can be a support to advisors' back-office activities (by

[4] In-Vivo is the union of 223 French cooperatives. It employs more than 6000 people and its gross income is above 6 billion euros. It has three main missions: buying inputs for farmers' cooperative, selling their products on agricultural commodities markets, and providing R&D for the union.

organising their data base, or by processing farmers' data to provide prescriptions, etc.). The difference stands in the role of advisory organisations in the development of the DST. By 'associated', we mean that the advisory organization did not contribute to the creation and development of the DST; they are only a partner for its diffusion. The DST was developed by other actors (research organization, private firms, etc) who provide it to advisory organisations, either on a free or commercial basis.

- **Excluded**: here we mean that advisory organisations do not play any role regarding the creation, development and diffusion of the DST. The DST is provided to farmers (either on a free or commercial basis) directly by organisations out of the field of advisory services (research institutes, universities, farmers' organisations, private organisations etc.).

We finally selected three cases that enable the combine of the two dimensions mentioned above.

4 General description of the case study

In this section, we describe the three cases studies more precisely, and how they relate to the structure and transformation of the French AKIS. For each DST studied, we present its objective and the interface on which it relies, but also its main source of knowledge and its model of diffusion (see table 5 in appendix).

4.1 The *Phytnes* DST

Phytnes is software that has been created by Invivo[5]'s (a union of cooperatives) for advisors. It aims to optimize their advice, due to an interface that allows access to a big database regarding different agricultural topics (regulation, geographical information, crop's diseases, inputs efficiency, etc.), but also to make recommendations based on these databases, to follow whether and how farmers applied these recommendation in practice, to ensure traceability, and to compare solutions.

- Interface: *Phytnes* takes the form of 'classical' software. Advisers can install it on their own computer.

- Sources of knowledge: The software has been created by Invivo's research team. All the knowledge comes from and is validated by this R&D department of the union of farmers' cooperatives.

- Diffusion: This software was first targeted to the advisors of the cooperatives member of the union. Invivo sells this service to these cooperatives that equip their advisors with the DST[6]. It is used by 650 advisors and covers more than 900 000 hectare (with a target of 3 million ha covered within 3 years).

- Integration of environmental goals: *Phytnes* has two interfaces: one for conventional farming and one for organic farming, which advisors can combine or select according to farmers' expectations.

[5] INVIVO is a union of cooperatives created in 2001, which regroups 241 French farmers' cooperatives, has a turn-over of €5.7 billions, and invests massively in R&D.

[6] The interface allows cooperative to personalize the software according to their specificities (portfolio of chemical inputs, seeds…). Farmers don't have to pay to benefit for a service based on this software.

4.2 The *Farmstar* DST

Farmstar is a service initiated in the context of a private-public partnership between a private company (*Airbus Defence and Space* [7]) and an applied research institute (*Arvalis*[8]). Based on satellite images and technologies of biomass measurement, this DST aims to optimize the fertilization of different crops (wheat, barley, triticale and rapeseed). The innovation consists of the DST enabling the integration of the geographical heterogeneity of plants' needs for nitrogen, in order to optimize fertilization.

- Interface: The DST consists of maps[9], where a colour gradient represents the intensity of plants' needs for nitrogen according to the position in the field. The farmer can receive either a paper version of this map or a numeric file, which can be uploaded to computer equipped precision machinery trucks based on Geographical Positioning Systems (GPS) technologies.

- Source of Knowledge: There are two main knowledge bases used in this DST: one for deriving biomass from satellite images, and another for modelling plants' needs for nitrogen given biomass and other variables. The first source of knowledge is *Airbus Defence and Space*. The second database is provided by applied research institutes (*ARVALIS* et *CETIOM*[10]), which have the status of farmers' associations but are supported by public funds.

- Diffusion: the *Farmstar* DST is sold by the *ARVALIS-AIRBUS* consortium to diverse advisory organisations (farmers' cooperatives, chambers of agriculture, some private companies, etc.) that are charged to commercialise it to farmers. This means that the consortium (*ARVALIS-Airbus*) that created the DST has chosen not to diffuse it directly, but to associate traditional advisory organisations that integrate the DST in the services that they supply to farmers. The service costs between 10 and 15 euros per hectare to farmers. Today, the DST is available in more than 50 "départements'' and diffused by thirty partners. In 2014, 661 000 ha were covered by *Farmstar* (380 000 on wheat, 205 000 on rapeseed, 72 000 on barley and 4000 on triticale). And the diffusion continues to grow.

- **Integration of environmental goal**: *Farmstar*'s technology claims that it allows farmers to reduce their nitrogen use by accounting for field heterogeneity[11].

4.3 The *Di@gnoplant* DST

Di@gnoplant is a DST that was developed by a research team of the National Institute for Agricultural Research (INRA[12]) based in Bordeaux. The background of this DST is a huge picture library of the main diseases of different crops (lettuce, tomato, zucchini, tobacco, melon and vineyards). It is associated with

[7] Airbus Defence and Space is a division of Airbus Group responsible for defense and aerospace products and services. It is present in dozens of countries on all continents. The FARMSTAR Service is developed by a unit based in Toulouse.
[8] Arvalis is an applied research institute for the cereal sector. It is an association owned by farmers. It is funded both by farmers' levees and with contracts from the Ministry responsible for Agriculture.
[9] Farmers receive three different maps at key moments of the year. The first map at the end of February allows the estimation of nitrogen absorbed by the vegetation cover and to calculate a total dose that the farmer will have to bring during his campaign. The second map is sent in mid- March. It estimates the number of stems on the plot and suggests a potential return. The third map is sent in mid-May when the last leaf of the plant is out. It allows the suggestion of a last nitrogen dose to reach the potential return purpose.
[10] Cetiom is an applied research institute equivalent to ARVALIS, but for the oilseed sector.
[11] 20 to 30 kg less nitrogen per hectare and per year on rapeseed and 10 to 20 kg less nitrogen on wheat
[12] The French National Institute for Agricultural Research (INRA) is a public research institute , employing 8500 people distributed between 17 regional centres and 13 research departments

a determination key that allows the user to identify the diseases or pests attacking their fields. Additionally, users can benefit from complete information about these pests, and can read some recommendations about how to fight against them. For this later aspect, the software is linked to a website of the French Ministry of Agriculture.

- Interface. The database is available on the website Ephytia[13]. The DST *Di@gnoplant* makes this database also available as a smartphone application for farmers and advisors.

- Source of Knowledge. The pest picture library and the determination key come from a research unit at INRA. Nowadays, INRA tries to develop some partnerships with other institutes (applied research institutes owned by farmers) to diversify their software on other plant species.

- Diffusion: *Di@gnoplant* is free. Users can download it on the Apple or Google store.

Overall, we can say that Phytnes was developed at the initiative of third-sector research, and that advisory services are integrated in its development; that *FARMSTAR* is embedded in a public-private partnership, and that advisory services are associated to its diffusion; and that *Di@gnoplant* was developed by a public research institute, and advisory services are not associated to it (table 1). The three cases combined together thus represent some of the major transformations of the French AKIS, including:

- A greater pluralism of advisory services, including farmers' cooperatives, private companies, etc.;
- The generalization of public-private partnerships in the services;
- Fuzzier boundaries between actors, where research institutes commercialise some DSTs and services for farmers, partially in a perspective of cost recovery;
- The growing R&D investments of farmers' cooperatives.

A comparison between the three situations will enable the understanding of how institutional arrangements (and the integration or not of traditional actors of advisory services in these arrangements) play on the ability of DST to: i) be an effective bridge between research and practice; ii) better integrate farmers' needs.

Table 1 Distribution of French main OAD according to the type of research partner involved and to the role of advisory services *(source: the authors)*

		Type of research partners involved			
		Public	**Third-sector (farmers' cooperatives)**	**Private**	**Public-Private networks**
Integration of advisory services	**Integrated**	* Azofert	* *Phytnes*		
	Associated	* Olympe * Logiciel de bien-être animal		* Plainciel * Viticiel	* *Farmstar* * ITK vigne
	Non Associated	* *Di@gnoplant* * Azodyn-Org		* Bay+Movistar * DECID'Herb * Gram'ID * Alphi-Net * Crop's Advice * DACOM	

[13] http://ephytia.inra.fr/fr/Home/index

5 Methods, data collection, and stakeholder involvement

Before describing the methods and data collection for the case study analysis, we have to acknowledge as a limit of the study that the involvement of stakeholders was rather restricted, due to time constraints. Nevertheless, we presented our hypotheses and the case selected to a group of experts gathered for a foresight exercise regarding the transformations of the French agricultural R&D system, horizon 2025. Our participation to this collaborative foresight study validated that the focus on DSTs is relevant. DSTs are acknowledged in this participative study as a major trend in the transformation of the knowledge flows within French AKIS. *FARMSTAR*, *Di@gnoplant* and *Phytnes* are regarded as relevant DSTs cases for discussing the new role of farm advice in the relations between research and practice.

Our study relies on a set of interviews with experts and stakeholders involved in the development and diffusion of the three DSTs. This includes researchers, employees of private firms, and staff of advisory organisations (advisors). In total, about 20 interviews were conducted (see appendix 1 for a list).

The methodology chosen for building the sample of interviewees was snowball sampling (Browne 2005). This methodology can be applied when the population targeted by a study cannot be identified ex-ante. This is the case in our study as we were unable to easily find data presenting the stakeholders involved in the development and diffusion of each DST. The methodology basically consists of asking each interviewee to indicate other actors involved in the innovation networks.

The questions included in the questionnaire (see appendix 1) aimed at understanding the dynamics and the governance of the partnerships that were institutionalized to create and diffuse the DST. The questionnaire was organized into seven sections:

- i) General information about the organization surveyed;
- ii) Description of the DST;
- iii) Strategy of economic development of the DST;
- iv) Procedure of validation of the scientific models supporting the DSTs and of their outputs;
- v) Structure and dynamics of the partnership institutionalized to develop the DST;
- vi) Relations with traditional advisory organisations of the French AKIS;
- vii) Monitoring of the impact and diffusion of the DST, and modalities of integration of farmers' needs and feedbacks.

As the focus of the case study is set on the links between research and practice, we chose to pay specific attention to the question of the validation of knowledge used in the DST. This function plays a key role in the functioning of AKIS: it enables farmers to rely on robust knowledge when they want to change practices or adopt innovations. The relations between applied research institutes and advisory organizations have historically played a key role in this function: by running field experiments in experimental stations or in networks of farms, by accumulating data, and by organizing training and conferences, etc. (Labarthe 2009). DSTs can potentially change these patterns, by connecting more directly science and practice. But the question of how the value of the knowledge supporting DSTs is validated for practice remains open, and may imply an active contribution of advisory services. In order to better understand these validation procedures, we identified three different steps:

1) The first step is the validation of the scientific knowledge supporting the DST, mainly agronomic and ecological knowledge. For the *Farmstar* case, this validation concerns not only the agro-ecological modeling (i.e. to calculate the plants' needs for nitrogen using data about soil, climate and biomass) and database (e.g. biomass measurement), but also modeling related to satellite images (i.e. how to calculate biomass from a measurement of infrared radiation by satellite). For *Phytnes* and *Di@gnoplant*, the validation is the one of all the data included in the DST (e.g. the pest picture library supporting the *Di@gnoplant* DST).

2) The second step deals with the validation of the predictions and recommendations of the DST. If the DST aims at providing prescriptions (e.g. how much nitrogen to spray for *Farmstar*), how are the validity and relevance of these prescriptions evaluated (given the specificities of each farm)?

3) The third step is the ex-post evaluation of the performance of the DST. If farmers applied the prescription of the DST, did they achieve the expected outcomes (e.g. yield and nitrogen losses in the case of *FARMSTAR*)?

The last section of the questionnaire aimed at analysing the specific contribution of advisory services to these three steps of validation of the DST, but also to the integration of farmers' needs in their design. In that respect, the case study approach is very relevant to differentiate the effects linked to the context from the effects associated to the object under study, here farm advice and DST (Yin 1989). The combination of the three case studies enables the testing of some theoretical assumptions (Sigglekow 2007) regarding the role of advisory services and knowledge flows within the agricultural sector, and to understand how institutional settings influence the contribution of farm advice towards the good functioning of DSTs for linking research and practice.

6 Results

6.1 Actors and sources of knowledge

In this section, we describe the sources of knowledge involved in the construction and diffusion of each DST, and the type of relations between research, advice and practices on which the DSTs are based. The knowledge flows are depicted in diagrams for each case.

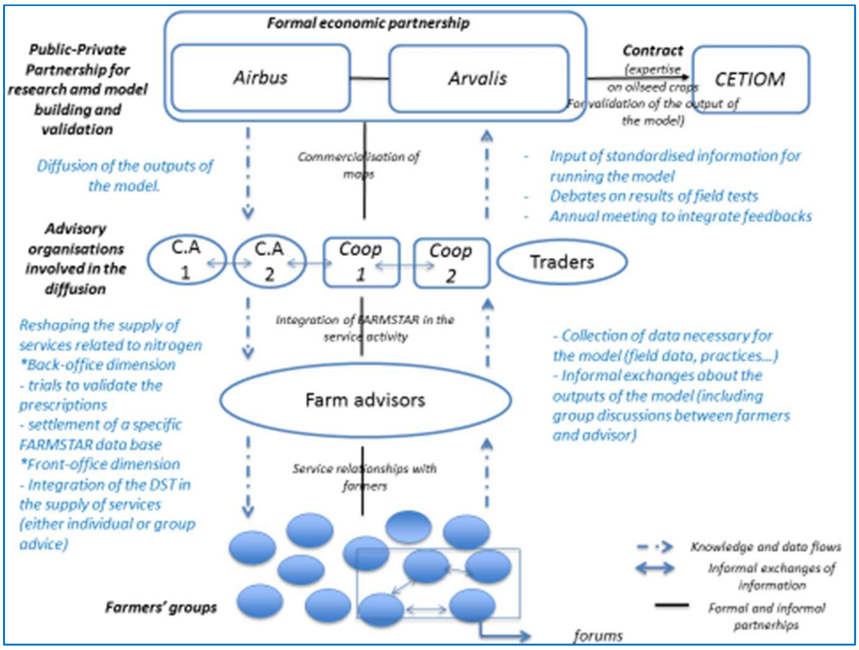
Main sources of knowledge and main knowledge flows in the three cases

*** Sources of knowledge of The *FARMSTAR* case:** *FARMSTAR* relies on a complex public-private partnership that associates many stakeholders, including advisory organisations. The exchange of knowledge within the network can be described as rather top-down exchanges (see figure 2). The main sources of knowledge are clearly the three research organizations (either private or public) that created and developed the DST:

- *Airbus Defense and Space* provides the knowledge that enables the calculation of Infrared (IR) radiations from satellite images, and collaborates with *ARVALIS* to produce a model to derive from the IR radiation proxys about the biomass of wheat, barley or rapeseed;
- *Arvalis* contributes to the model of biomass estimation, and also to the agronomic model calculating nitrogen needs given this biomass and other variables collected at field level;
- The *Cetiom* plays the equivalent role for rapeseed production.

These models enable the production of maps describing plant needs for nitrogen according to the position in the field. These maps can be considered as intangible goods (following the definition of Hill 1999) that impart scientific knowledge. These maps are sold by the *Arvalis-Airbus* consortium to advisory organizations which are charged to diffuse them to farmers. These organisations may be farmers' cooperatives, chambers of agriculture, or private traders.

Figure 2 The Knowledge flows in the *FARMSTAR* case *(source: the authors)*



The contracts also imply that the advisory organization (i.e. the clients of the *FARMSTAR* service) provide information and data to the consortium. This means that there is also a bottom-up flow of data from the users to the research organisations. However, this flow cannot truly be considered a real exchange of knowledge, but rather a data flow. These data (delimitation of farmers' field, yield targeted by farmer on that field, former crop cultivated, list of farmers' practices, etc.) provide the information necessary for *Arvalis*, *Airbus* and *Cetiom* to run their models and produce the maps. This information flow is integrated in a kind of industrial chain of production of the DST, standardized by *Airbus*, which advisory organisations (farmers' chambers and cooperatives) have to comply with.

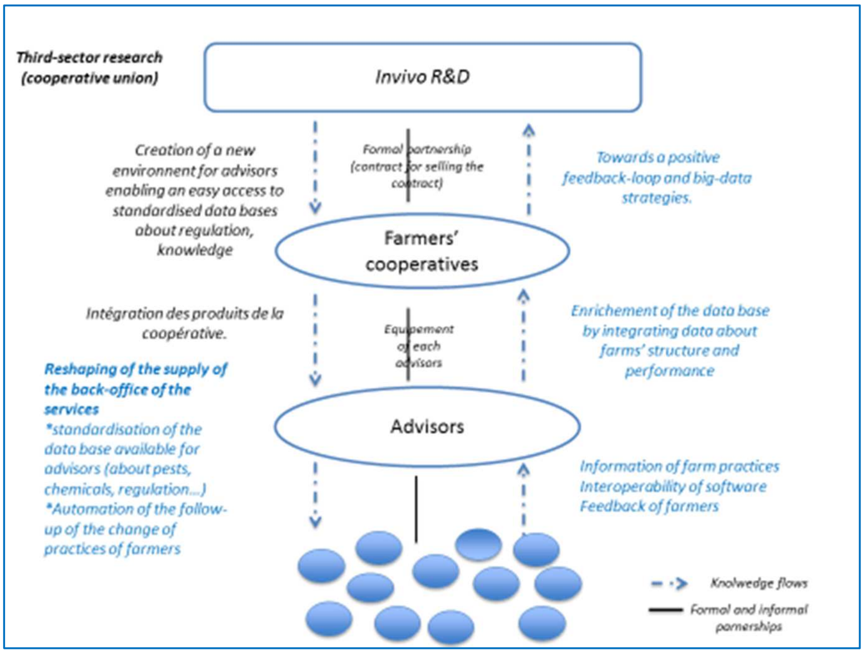
These advisory organisations are then responsible for selling the maps to farmers. The diffusion of the *FARMSTAR* DST is thus integrated in the global supply of services of farmers' cooperatives and chambers that contracted with *Airbus* and *Arvalis*. These advisory organisations are in charge of combining *FARMSTAR* knowledge with other sources of knowledge that may impact farmers' choices regarding fertilization. This may involve horizontal exchanges between farmers (with the integration of *FARMSTAR* in group advice for instance).

In the two other cases, the situation is easier to describe. These DST are at the initiative of a single organization that invest in R&D activities to develop the DST and who diffuses it.

***Sources of knowledge of *Phytnes* case.** In the *Phytnes* case, the DST is at the initiative of a union of farmers' cooperatives (InVIVO). The aim is to equip advisors with software that connects with every database that they need for their activity (regarding the efficiency of the various inputs available for farmers, regulation concerning these inputs, etc.). The database linked with these DST are provided by the InVivo R&D team (see figure 3) from a rather top-down perspective. Nevertheless, the software allows an inter-operability with any database used by advisers in their interactions with farmers.

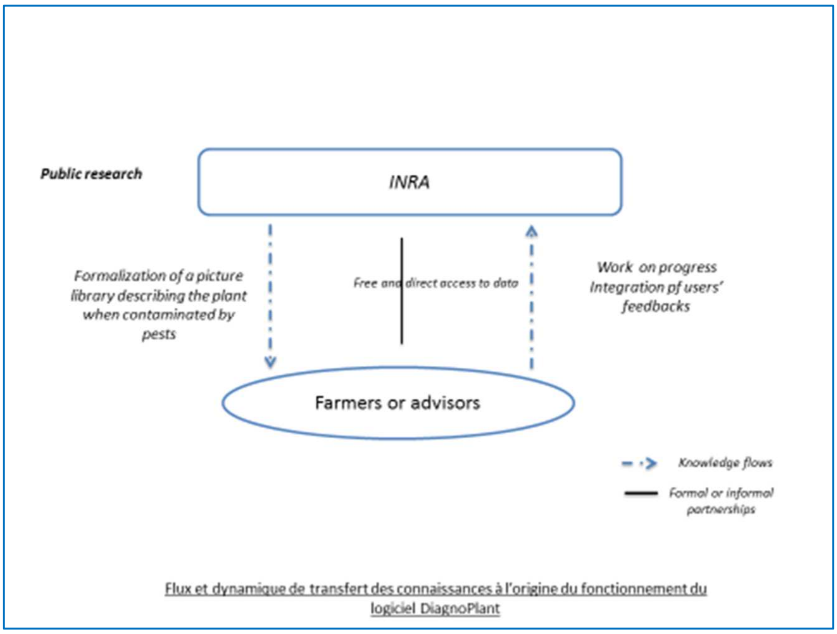
There is a willingness to integrate farmers' data into the software (regarding the structure or their farms, their practices, etc.). However, the farmers remain rather passive in this process. The integration of farmer data is implemented by the adviser. The aim is to be able to follow in a more standardized and systematic way the evolution of farmers' practices and to monitor whether or not they followed the advisors' recommendations.

Figure 3 The knowledge flows in the *Phytnes* case *(source: the authors)*



***Sources of knowledge of *Di@gnoplant* case.** In this case, the DST is fully at the initiative of a research team of the National Institute for Agricultural Research (INRA), and more specifically of a researcher who accumulated a formalized picture library of pests contaminating fields of tomato, vineyard, tobacco, etc. This researcher has seen a potential for a better use in practice of the picture library with ICTs (internet and smartphone applications). The DST relies not only on a big data set, but also on knowledge formalized in a set of rules that together form a determination key to identify the pest present in a given field (see figure 4). There isn't at this stage any form of bottom-up knowledge flows: the picture library is a cognitive resource available to anyone, and INRA does not ensure any follow up about how this resource is used in practice.

Figure 4 The knowledge flows in the *Di@gnoplant* case *(source: the authors)*



Summary of preliminary findings: knowledge sources and knowledge flows in the context of DSTs

In the three cases, the DSTs are at the initiative of research organizations (public, private, or third sector), who are at the main source of knowledge. The innovation networks associated with the DSTs are embedded in a rather top-down dynamic, where the organisations providing the R&D might impose the rules and procedures for knowledge exchange. This has an impact on key questions of PROAKIS WP4 regarding the transformation of knowledge flows within the agricultural sector.

- **Changes in the sources of information and hierarchy of these sources, and who participates in sharing information**. In all three cases, the main source of knowledge tends to be research, and the other sources of information (farmers, advisory organisations) do not rank at the same level in the functioning of the DST. They tend to be restricted as sources of information to run models, or as feedbacks to enhance the accuracy of the models' parameters. Some DSTs do not involve any form of feedback. In all three cases, there are some advisory organisations clearly excluded from the development of the DST. For instance, it is striking to consider that the Chambers of Agriculture played a minimal role in the development of any of the three DSTs.

- **Changes in the role of the farmers**. The farmers are regarded as final users of intangible goods (maps, picture libraries…) rather than as co-producers of the knowledge embedded in the DST. Thus, the DST may be seen as a new form of cognitive resource that farmers can interrogate to adapt their practices and production systems.

- **Changes in the links with farmers and in how they relate to advisory services**. Not all of the three DSTs claim to change the adviser-farmer relationship. This is the case, for instance, of the *Farmstar* and *Di@gnoplant* tools that are presented as new shared cognitive resources for both farmers and advisers. The integration of the DST in the service relationship is under the responsibility of the advisory organization using the DST. At first sight, it might give more transparency in the scientific argumentation of advisors when interacting with farmers. The *Phytnes* DST is rather different, as it aims at standardizing some of the exchanges of data between farmers and advisers.

- **Changes in the research-advice interaction induced by the DST**. This is a major dimension of the transformation induced by DSTs within AKIS: they transform the procedures for knowledge exchange and practices between research and advice. In the next section, we will show how these transformations are linked to the formal partnership and economic strategies associated to each DST. These strategies have consequences on knowledge flows and content.

6.2 Content of the knowledge exchanged and processes supporting these exchanges

At first glance, the development of DST might be associated with the new opportunities opened by ICTs to embed the use of scientific knowledge in practice for farmers. But it is also the expression of the willingness of different actors to develop new services for farmers, whereas this was not formerly their mission or activity. In the three cases, as described in the section above, research organisations (either public or private) are central in the knowledge flows. They invest in R&D and have strategies to generate new knowledge flows within the sector, and to earn value and returns out of these knowledge flows. These strategies not only change the procedures for knowledge exchange within AKIS, but also the very content of knowledge.

Discussing the consequences of DSTs on knowledge flows and content implies the categorization of the knowledge exchanged. We cannot provide an exhaustive overview of the debates about these categorizations in this report. Two types of distinctions are particularly relevant for our study. The first is Polanyi's (1967) classical distinction between tacit ("we know more than we can tell") and codified knowledge ("we can write and transfer all that we know"). Nonaka (1994) have indicated well that procedures of knowledge exchange would vary according to the nature of knowledge[14].

[14] Exchanging codified knowledge might be done due to standardized procedures and supports (textbooks, software, etc), whereas exchanging tacit knowledge implies high levels of socialisation (Nonaka 1994).

The second question is about the types of empirical evidence that are used to support the knowledge flows. There could be different types of evidence supported by knowledge flows (Berriet et al. 2014): evidence of presence[15]; evidence of difference-making[16]; or evidence of mechanisms[17].

Potentially advisory services might use and combine both type of knowledge (tacit and codified) supported by different types of evidence (evidence of presence, of difference-making or of mechanism). The three cases show clearly that DST tends to increase the codification of the knowledge flows. and that this tendency varies according to whether the DST implies knowledge flows about evidence of presence, or about evidence of mechanism and difference-making.

Towards a standardisation of knowledge flows within AKIS?

A common feature of the three DSTs under study is that they lead to the storage and exchange of very large amounts of data. To enhance the efficiency of these exchanges of data, there is for each DST a clear tendency not only of standardizing the procedures for exchanging data, but also the knowledge produced.

* This is particularly true in the *Farmstar* case. The whole project relies on the combination of data coming from different sources: data from satellite images (to evaluate biomass) and data from farmers' fields (field delimitations, farmer practices, etc). This must be done in a very precise and tight timing. The aim of the DST is to produce operational advice (how much nitrogen to spray when and where). This means that the outcomes of the modelling (the map) must be available in a very precise timing for farmers. To achieve this, the [*Airbus-Arvalis-Cetiom*] consortium has established some standardized procedures for collecting information about farmers' practices. This task is fully delegated to the clients- that is the advisory organisation (chambers, cooperatives) buying the service to the consortium and selling it to farmers. *Farmstar* represents more than commercialising an intangible good (Hill 1999) for these advisory suppliers. It involves organisational innovations, both internal ones (i.e. the exchange of data and information between advisors and farmers), and external ones related to relations within innovation networks. The knowledge exchanged is mostly codified knowledge, and integrated in the main support of *Farmstar*: the map. *Airbus*, *Arvalis* and *Cetiom* tend to integrate as much knowledge as possible in the numeric map; and to reduce as much as possible any direct interactions with their clients (formal or informal) to diffuse the map. The interactions mostly aim at validating and calibrating the model, as we will see in the next section.

* In the *Phythnes* case, standardisation and codification of knowledge are at the very centre of the project of the DST. The aim is to integrate different sources of data and provide them in a standard environment to advisors. This takes the form of software that integrates access to all databases required by the activity

[15] Evidence of presence aims at the description and verification of a thing which exists on the ground (e.g. pests observed in a given field). It is used to build an agreement among different stakeholders on the state of the world (e.g. before and after pest control action).

[16] Evidence of difference-making can be evidence of effectiveness: evidence that a given action yields the desired result (e.g. improved yield following the implementation of a given recommendation of nitrogen input).

[17] Evidence of a mechanism for a phenomenon is produced when there is evidence that the entities or the activities that make up a mechanism, and the organization of these entities and activities by which they produced the phenomenon, are known (e.g. the bio-chemical reactions needed for an increase in fertilizer to increase crop yield in a controlled environment).

of advisors. Here again, the development of informal knowledge exchange tends to be limited, and the new requirements that customers may have shall be integrated in new version of the software interface.

* In the *Di@gnoplant* case, the codification and standardisation goes one step further. The aim is to provide codified knowledge to users (a picture library and a determination key). This means that the users should be able to use the knowledge without any other interactions with the conceivers or the DST, i.e. to identify the pest contaminating the fields autonomously.

In the three cases, there is a clear willingness to formalize the knowledge exchanges as much as possible. The codification of knowledge is expected to reduce the costs that would be associated to the interactions needed to exchange tacit knowledge. This is linked to the economic strategies of the various DSTs.

Towards a formalization of the partnership within AKIS

The willingness of various research actors to create value out of DSTs tends to formalize the relation between traditional actors of the French AKIS, including new forms of public-private partnerships and commercial contracts, sometimes integrating intellectual property rights (IPR) issues.

* The *Farmstar* project has been initiated by *Airbus*. The aim of *Airbus* was to find new ways of producing value from the images generated by the satellites that are launched and controlled by the company. The idea of *Airbus* was to find new domains of service applications for satellite technologies, including agriculture and environmental applications. Therefore, *Airbus* has established research projects together with applied research institutes in the agricultural sector, namely *ARVALIS*. The aim of this project was to generate new knowledge, and to test prototype versions of the DST. Later, a formal partnership was created by the two entities, so as to diffuse the DST. This partnership was formalized into contracts, including the distribution of IPRs between the two associated partners, regarding who brought which knowledge for the development of the DST and the associated algorithms. Another formal contract was signed with a second applied research institute, the *CETIOM*, specialising in research for oilseed, so as to develop an application for rapeseed. The consortium then sold the DST to advisory organisations who are charged to diffuse it to farmers. The advisory organisations are 'clients' of the service: they will receive the maps provided they pay and they supply all the necessary data from farms following the schedule provided by the consortium. The consortium sells large maps to advisory organisations (focussing on a few square kilometres), who are then responsible for selling individual maps derived from the large maps to individual farmers. They integrate these maps in their supply of services, either in individual or collective forms of advisory services. This generates some networks effects. If a farmer wants to benefit from a certain dimensions of the service, then she/he must subscribe to *Farmstar*. Subsequently, *Farmstar* is becoming little by little the standard for nitrogen fertilisation in France.

* The strategy behind the development of the *Phytnes* DST is grounded in the context of increased complexity in the conditions of agricultural production in France and of increased fragmentation of the French AKIS. Farmers need to comply with more and more standards, coming from regulation (European or French standards about environment, sanitary quality, etc.) or from downstream agro-food industries. This generates many flows of information from and to the farmers, which can be rather fragmented, both

for farmers and advisors. In this context, the ambition of *Phytnes* is to become a unique portal from where the advisors will be able to access all the relevant information that they need. The idea of the promoter is that *Phytnes* will become the “Windows” of French agriculture. *Phytnes* will be compatible with any software application available for farmers and advisors. But *Phytnes* would be the standard system for organising advisors’ knowledge and information. *InVivo* sells the software to advisory organisations though a formal commercial contract. The clients are, for the moment, the cooperatives members of the union. However, the ambition is to go beyond and sell it to other types of advisory organisations. Like *Farmstar*, it is also strongly based on the assumption of positive network externalities effects: the different advisory organisations, but also other AKIS organisations, will have to buy *Phytnes* if they want to access various data base available in the agricultural sector.

* The strategy of *Di@gnoplant* is completely different. It was more an individual initiative of a researcher within INRA who wanted to make some knowledge available for users, i.e. a picture library and determination key of pests in the horticultural sector. There is no economic strategy behind the project. The website and smartphone application are available for free. However, such an initiative fits with the strategy of INRA to have a better impact in practice. It also corresponds well to a trend in the French AKIS where some basic or applied research institutes tend to develop new applications and services for end-users (with an accountability perspective).

In the three cases, the DST is clearly at the initiative of research actors that try to develop new services for end-users. These new strategies change the functioning of the AKIS, with more standardisation of knowledge flows and a formalisation of the partnerships supporting these knowledge flows. Nonetheless, the question of the integration of farmers’ needs in these procedures remains open.

The integration of farmers’ needs still under question

As a preliminary result, we can say that the integration of end-users varies greatly from one case to another, according to the strategies followed by the research organisation at project initiation, but also according to the knowledge content exchanged. We will illustrate this point through a comparison between the *Farmstar* and *Di@gnoplant* cases.

* In the case of *Di@gnoplant*, there is no interaction between the creators of the DST and the users. There is no monitoring of the modalities of how the DST is actually used by the end-users, therefore there is no data regarding who the users are and what they use the application for. This is quite related to the knowledge content of the DST. The aim is to produce what Lündvall and Johnson (1994) would depict as know-how, that is knowledge describing the state of the world. This implies the production of shared and robust evidence of presence: standardized methods enabling the determination of the presence or absence of a given pest. In order to be shared by every actor, such knowledge must be perfectly codified: the determination key shall be explicit, accessible and sufficient to determine the presence of the pest without any other source of knowledge. As no tacit knowledge is needed, the interaction with farmers or advisors might not be necessary. The situation would be different if the DST had the ambition to include evidence of mechanisms and of difference-making, with the aim to propose solutions to fight against the

pest. Nevertheless, there are some perspectives in that respect: feedback from farmers could enable the production of big data about the diffusion of the different pests across territories.

* The *FARMSTAR* situation is different: the aim here is to provide solutions for farmers. It is not only a question of know-how, but also a question of know-why, i.e. a question of understanding why it would be necessary to spray a certain quantity of nitrogen at a certain time to maximize yield and minimize nitrogen loss in the environment. This implies the accumulation of "evidence of mechanisms" (i.e. empirical evidence that would allow the understanding of the mechanisms by which nitrogen spraying would contribute to better yields). This is precisely the objective of the *Airbus-Arvalis-Cetiom* consortium, which combines different types of knowledge bases (agronomic, ecological, soil sciences, etc.) to propose a simplified model of plant needs for nitrogen according to the position of plants in the field. This is done within the consortium with codified knowledge which is diffused to farmers and advisors due to the map. The knowledge is perfectly codified and can even be transferred to farmers as a numeric file, which the farmer can upload on the computer of his/her tractor to automatically adjust the quantity of nitrogen sprayed according to the position in the field (if the tractor is equipped with GPS and precision farming technologies). Nevertheless, the consortium *Airbus-Arvalis* made the choice not to sell the DST directly to farmers, but rather to diffuse it through traditional advisory services. This might indicate that the transmission of codified knowledge might not be sufficient to support farmers in their decision-making about fertilising, and that it is necessary to integrate other farmers' knowledge, including tacit knowledge (about soil, farmers' preferences, etc.). This integration of end-users knowledge remains the role of advisory services.

Summary of preliminary findings about content and methods of knowledge exchanges in the context of DST

The three case studies enable the better understand of how DSTs may change the content and methods of the knowledge flows within French AKIS.

- A first change stems from the **procedures of the knowledge exchange** (importance of research, nature of formal or informal partnerships, methods, etc.). In the three cases, the DST is clearly at the initiative of a research actor, sometimes outside of the agricultural sector. In the *Farmstar* case, the project of the DST has been launched by a new player from the private sector (*Airbus*). This has induced some changes in the relations between some traditional actors of the French AKIS, including applied research institutes and advisory organisations (chambers of agriculture, farmers' cooperatives, etc.). The relations between these actors are embedded in a very long tradition of interactions within an AKIS supported by public policies, where informal relations were very important. The diffusion of the DSTs is one of the elements that leads to a growing formalisation and contracting of the relations between these actors. Different actors (research organisation, private companies, etc.) tend to codify their knowledge into intangible goods that they commercialise to other actors of the French AKIS. They want to promote their DSTs as new standards within AKIS.

- In terms of changes in **knowledge content**, it appears that the topic of knowledge embedded in the DST is mainly defined by the agenda of the research organisations launching the DST. The integration of societal concern and public issues depends on the incentives of these organisations to do so. If the integration of environmental goals is clearly on the agenda of INRA when diffusing *Di@gnoplant*, such goals might be less central for other DSTs developed by industries.

In the three cases, the development of DST comes together with a growing codification of the knowledge exchanged. But in any case, the question of the empirical validity of the knowledge for practice remains open, and raises the issue of the role that advisory services might play with regard to this validation.

6.3 The role of advisory services vis-à-vis DSTs development

It is not possible to highlight all the functions that advisory services might play in the development of the three DSTs. We chose to focus on a major function of advisory services: the validation of knowledge. As DSTs claim to provide scientific knowledge directly to farmers, it seems all the more important to validate the robustness and relevance of this knowledge in practice for farmers.

The three DSTs provide farmers and/or advisors with different sets of empirical evidence: evidence of presence of pests (in the case of the pest library of *Di@gnoplant*), evidence of mechanisms of plants' needs for nitrogen (in the case of the map provided by *Farmstar*), and a very complex set of evidence in the case of *Phytnes*. Tables 2, 3 and 4 present the role of advisory services in the three steps of validation of the DST (as described in the methods section) respectively for *Farmstar*, *Phytnes* and *Di@gnoplant*.

* In the *FARMSTAR* case, there are two key components in the construction of the evidence of mechanisms: the model that links satellite images to biomass estimation, and the model that relates biomass to nitrogen needs. These models are elaborated by the consortium *Airbus-Arvalis-Cetiom*.

- The two applied research institutes are responsible for validating the biomass prediction. They compare the biomass estimated by the model with one actually measured on direct field samples (in experimental fields). This means that the models are only validated by the members of the consortium, resulting in strong asymmetries of knowledge between actors. The advisory organisations (chambers or cooperatives) diffusing the DST do not have the opportunity and capability to assess the quality of the model.
- The relevance of the outputs of the DST is discussed with the advisory organisations that diffuse this service. Some of them have established experiments where they compare the estimation of nitrogen needs calculated by *FARMSTAR* with the same needs calculated by other methods (for instance based on direct field measurement). Nevertheless, such investigations are far for being systematic, and are scarce. The DST suffers from a lack of bottom-up information providing feedback on the accuracy of the model *vis-à-vis* alternative methods.
- The third step of validation is that of the result of the prescription: did farmers reach the desired outcomes (in terms of yield, income, nitrogen use and loss) after they followed advice from *FARMSTAR*? This task of validation is implemented by advisory organisations. Some early experiments were undertaken by farmers' cooperatives, through both interviews and follow-up of the practices implemented by farmers at the very early stages of diffusion of FARMSTAR. It is claimed by the consortium that such studies demonstrated that the DST enables the reduction of nitrogen use by 30kg per hectare of wheat and 15kg per ha of rapeseed, and reduces costs by 70 euros per hectares (including the cost of the service). If these figures are heavily used by the consortium to demonstrate the performance of *Farmstar*, we couldn't find any source, report or methodology for this data.

Table 2 What role for farm advice in the empirical validation of the DST in the *Farmstar* case *(source: the authors)*

Validation of scientific models supporting the DST	The validation of the models is under the responsibility of the Consortium. -*Airbus* is in charge of validating the model calculating IR radiation variations from satellite images. This is done by comparing satellite images with pictures taken by planes on control fields - The validation of the agronomic part of the model (calculating the needs for nitrogen from the IR radiation and a few farm data). This is mainly done by comparing the fields' biomass as estimated by the model, and as measured in control fields within *ARVALIS* and *CETIOM* experimental stations. → Farm advisory services do not play any role at that stage
Validation of the recommendation of the DST	The validation of the recommendations is also mainly under the responsibility of the consortium - *ARVALIS* has settled standardized procedures to compare the outputs of the models (recommendation of the quantity of nitrogen to spray) with some data accumulated from local practices. This is under the responsibility of the regional researchers of *ARVALIS* and *CETIOM*. For instance, they remove any advice that recommend more or less than 25% of the average treatment in the area. → Farm advisory services are only marginally associated to this stage of validation by sending feedbacks to the main actors of the consortium.
Validation of the effectiveness of applying the DST recommendation	There is no systematic follow up of the performance of farms that apply the recommendation of the DST provided by the consortium. → Some farm advisory services claim that they did. But we couldn't have access to any of these studies.

* The software *Phytnes* involves a less complicated procedure of validation. The software consists of combining and providing different databases. The validation is exclusively realized by the R&D unit of In-Vivo which has 60 employees, 20 of which work exclusively on the acquisition and consolidation of the agronomic database, and a further 20 are computer scientists, in charge of developing software and applications.

Table 3 What role for advice in the empirical validation of the DST (the *Phytnes* case) *(source: the authors)*

Validation of scientific models supporting the DST	The validation of the databases included in the Phytnès software is under the exclusive responsibility of IN VIVO R&D. This R&D unit has more than 60 employees, among which more than 25 are exclusively dedicated to the actualization of the data and knowledge integrated in the *Phytnes* software. → The advisory services of the cooperative are not integrated in this validation process. They can nevertheless be some feedbacks by the cooperatives client of the service, as well as some integration of some of the data base of the client within the *Phytnes* data.
Validation of the recommendation of the DST	The recommendations derived from the DST are only under the responsibility of the cooperative client of the service. There is no validation of this yet. → the validation at that stage is fully delegated to the client
Validation of the effectiveness of applying the DST recommendation	This is an important ambition of the software. It should enable the advisors to integrate the change in farmers' practices, and to receive automatic warning when farmers do not follow recommendations. → the validation at that stage is fully delegated to the cooperative client of the services.

* The situation is rather similar for *Di@gnoplant*: both the picture library and the rules of the determination key are validated only by the research staff of INRA developing the DST. The DST does not provide any recommendations about how to fight the pest identified. This means that the DST aims to provide a key for validating evidence of presence of the pest. For any other type of evidence, the DST forwards the users to the website of the Ministry of Agriculture which lists solutions (chemical or non-chemical) available to fight against the various pests that can be identified with the DST.

Table 4 What role for farm advice in the empirical validation of the DST in the *Di@gnoplant* case *(source: the authors)*

Validation of scientific models supporting the DST	The validation of the data (the picture library) is validated by INRA only. --> For the moment, farm advice is not involved in validating the database. But there is a project of validating the diffusion of the pests by involving advisory organisations.
Validation of the recommendation of the DST	The aim of the DST is to help to identify the pests, not to propose or recommend some technical solutions to deal with the pest. For this latter issue, the DST forwards the user to the website of the Ministry of Agriculture, where the available solutions are listed. -- > For the moment, the advisory organisation is responsible for the validation of its own recommendations.
Validation of the effectiveness of applying the DST recommendation	No follow-up of the use of the DST so far.

Overall, it appears that the role of advisory service changes according to i) the type of knowledge and evidence produced by the DST; ii) the institutional settings that characterize the networks created to develop and diffuse the DST.

In the case where the DST only produce evidence of presence, the advisory services might not play any role in the validation of the DST, but they may have several other functions, for instance in the integration of this evidence with other sources of knowledge, to support farmers in changing their practices or production systems.

The *Farmstar* case is different. The aim is not only to produce evidence of presence, but to propose evidence of mechanisms that may support directly the choice of farmers regarding nitrogen fertilization. Here, there could be a broader impact on advisory services that could potentially be substituted by the DST. Nevertheless, as we will state in the concluding section, the impact of the DST seems much stronger in the back-office dimension of the services rather than in this front-office dimension.

7 Discuss and assess the performance of the knowledge flows and identify best-fit practices for advisory services

The comparison of the three cases enables some conditions to be highlighted under which combining DSTs and advisory services can be effective to support knowledge flows in the context of the French AKIS.

First, it appears that DSTs providing evidence of presence might have real potential in enhancing the quality of the knowledge flows and the relations between partners within AKIS. *Di@gnoplant* is a good illustration. It provides every other actor of the system with the same type of knowledge: the rules about how to determine the presence of pest in the field, and the empirical evidence to validate the diagnostic (a pest picture library). It can give more transparency in the relations between farmers and advisers, by providing them with the same evidence. In addition, it leaves it open how to design, on the basis of the DST, the advisory service that would make it possible to integrate this knowledge with other sources according to the situation of each farm. The conditions for this success are that the DST provides knowledge: i) perfectly codified; ii) supported by accessible evidence produced with transparent methodology; iii) with the perspective of integrating end users feedback.

The case of *Farmstar* is a different situation. At first sight, it also provides farmers and advisers with a common source of knowledge: a map of plant needs for nitrogen. But this knowledge is of different nature. It does not impart evidence of presence only, but also evidence of mechanisms. This means that the knowledge communicated is of a much more complex nature: it is made up of a set of hypotheses regarding how to relate the dynamics of growth of a population of plants to the needs for nitrogen. In such conditions, the *FARMSTAR* case highlights some specific difficulties that may be induced by the institutional settings supporting the development of such DSTs.

The presence of a big private company as main source of knowledge could generate strong imbalances of power and asymmetries of knowledge. The private firms seek to create value from their knowledge though the commercialization of the DST. As a result, they might be reluctant to share their knowledge base and information about the validation of the DST. Such cognitive resources are an important economic asset of the firm, protected by formal (i.e. IPR) or informal institutions. This makes it difficult for farm advice to contribute to the validation of the value of knowledge for farmers, as they cannot access this knowledge.

Overall, it appears that advisory services still have a role to play in the integration of knowledge and in the validation of DST. But they can be constrained by new institutional arrangements with industrial partners. In this context, they may have less power to validate the models and their outcomes. The situation could even become more complicated, as new industries in France (such as the big firms producing pesticides and chemical inputs: Bayer, Singeta, etc.) have developed some partnerships with ICT SMEs, in order to develop DSTs for farmers. In such a context, there is a risk that some DSTs could generate knowledge and advice biased towards production systems based on the intensive use of chemicals.

8 Conclusions

In this concluding section, we discuss how the development of DSTs transforms the contribution of advisory services to knowledge flows within French AKIS, and to the integration of farmers needs in these knowledge flows. We propose to discuss this by differentiating the effects in terms of 'front-office' and 'back-office'. We began the investigation with the hypothesis that DSTs would mostly affect the front-office dimension of the service. Since they consist of new interfaces connecting directly research and farmers, they could "bypass" advisory services. However, this does not seem to be the case. Rather, they seem to be new cognitive resources for the farmer-adviser service relationship. Such a relationship appears to still be necessary to integrate heterogeneous knowledge and support farmers' decision. Nevertheless, DSTs seem to have a great potential impact on advisory services, by downsizing their role in the production of evidence (in their back-office) supporting knowledge flows between research and practice.

*** DST and Front-office: are advisory services bypassed or do they still have a role to play for integrating knowledge?**

The three DSTs affect the farmers-adviser relationship differently, and it might a bit be too early to fully assess the changes induced in these relationships. Nevertheless, it seems that the front-office dimension of advisory services still have an important role to play in the integration of various knowledge flows at farm level.

Both *FARMSTAR* and *Di@gnoplant* could induce a potential bypass of advisory services, as famers could directly use them as intangible goods, transferred by research organization. These intangible goods are the map of plants' nitrogen needs in the case of Farmstar, or access to the pest pictures library in the *Di@gnoplant* case. They could be accessed or purchased directly by farmers thanks to ICTs. In such an extreme view, the role of advisors could be restricted to ensuring the follow-up of exchange of data between the DST suppliers and farmers, and to validating the quality of these data. Such a role might be only needed in the early stages of the DST, as this could be automatized later on. However, such a view is likely to be largely theoretical, as our field investigations show that advisory services still play a key role in the integration of knowledge flows from the DSTs with other sources of knowledge. And advisory services are also necessary for articulating heterogeneous knowledge needs coming from diverse types of farms and farmers.

This can be well illustrated with the *FARMSTAR* case. The promoter of the DST had different options to disseminate their maps. The first was an internet portal where farmers could have directly bought the map or numeric files. This was tried previously in a different project, but failed. *Arvalis* and *Airbus* were convinced that their DST could only be successful if it is integrated in a more 'classical' supply of advisory services from the Chambers of Agriculture or farmers' cooperative. Concretely, *FARMSTAR* is sold within a package of services, where the use of the DST is coupled with more classical forms of advice based on one-to-one interactions between farmers and advisers or group advice. This has enabled them to articulate the heterogeneity of farmers' demands. For instance, a Chamber has used the DST for group advice.

Farmers bring their maps during tours of fields: the maps are used to compare perceptions on nitrogen needs with observations at field levels. This has enabled the revitalization of exchanges of knowledge between farmers about fertilization. This also generates network effects to the benefit of *FARMSTAR*. To participate in these groups for knowledge exchange, farmers have to buy the DST, even farmers who are not equipped with precision farming machinery.

The two other DSTs might be considered to be more designed for advisors, rather than directly for farmers. They do not aim directly at bypassing front-office activities of advisers, but they may impact them. We imagine that *Di@gnoplant* may change relations between farmers and advisers by providing a shared and transparent diagnostic of pest contamination. For *Phytnes*, it could lead to a form of standardization of the front-office relations between farmers and advisors, where the changes in farmers' practices are registered and related to the recommendations they were given by the advisor.

Nonetheless in the three cases studied, the DSTs seem to be integrated in the supply of advisory services, rather than aiming to bypass it. One indication of this is that each DST is thought to be as much interoperable as possible with other DSTs and advisory services.

*** DST and back-office: standardization, contracting and asymmetries of knowledge**

At first sight, DST can be thought as a new way for advisors or farmers and advisors to directly access scientific knowledge in forms that fit with practice (maps, pictures, smartphone interface….). However, DSTs are more than simply new channels for generating knowledge flows between research and practice. They induce major change of the functioning of the back-office of advisory services. The DSTs are not at the initiative of advisory organizations. They are produced by other organisations that follow their own specific agendas, and induce changes in the rules shaping knowledge flows within AKIS. We can highlight three major changes:

- **Standardization**: the three cases are characterized by a very strong trend of standardisation of the knowledge flows within AKIS. In all three cases, there are some exchanges of codified knowledge, and the construction of a standardized database that belongs to the research organisation that created the DST. The standardisation of the knowledge base fits the requirements of the research organisation, not those of the advisory ones.

- **Contracting:** the three DST are at the initiatives of actors willing to play new roles within AKIS: (i) public research institute willing to have an impact in practice; (ii) industries looking for new areas of profitability in the agricultural sector; or (iii) private actors, trying to set new standards within the AKIS. For *Di@gnoplant*, the aim of INRA is to increase its impact on practice. In the case of *FARMSTAR*, the aim of the consortium is to build profit by selling an intangible good to the agricultural sector, and to become the new standard for fertilisation monitoring in France. The relations in the *FARMSTAR* innovation network correspond to that of an industrial project: they are formalized within contracts that set the responsibilities of each partners and also the Intellectual Property Rights that may be associated to these exchanges. For *Phytnes*, this goes one step further. The union of cooperative has invested lots of time and money to equip advisors with this new equipment. They want to get a return for this investment by selling it to all farmers' cooperatives, and even beyond, to other actors of advisory services, becoming the standard of farm advisor's computer portals.

- This situation of standardization and contracting of the knowledge flows induced in AKIS by DST could lead to the existence of **asymmetries of knowledge** between actors. In France, since the 1960s, there has been a very strong influence of farm advisory services in the monitoring of knowledge flows within the sector. This was the case, for instance, with the co-management of investments for the production of evidence through experiments in experimental stations. This was done through cooperation between applied research and advisory services, and managed by both formal (i.e. scientific committees) and informal institutions. With the DST, the relations are different. Farm advisory services are more in the position of being clients of the DST suppliers, rather than than co-producers of knowledge. This means that they buy intangible goods enabling new opportunities to access scientific knowledge useful for practice. But this also means that they do not have access to all the knowledge used to build these intangible goods, including the empirical evidence used for validation. This also means that it might be more difficult for them to play a feedback role for integrating farmer needs in the design of the DSTs.

* **Towards new difficulties to integrate the needs of certain farmers' groups in the conception of the DST?**

One dimension of the development of DST that we couldn't explore thoroughly is the question of the integration of the diversity of farms in the very conception of DSTs. It appears that advisory service organisations may have some difficulty in integrating the diversity of farmer needs in the design of DST. This can be illustrated with the situation of small farms (Labarthe and Laurent 2013) regarding the *Farmstar* DST. This DST does not allow the coverage of fields of less than 3.5 hectares. An adaptation of the DST for small fields is possible but it would require some specific back-office work (i.e. specific algorithms). However, *FARMSTAR* and *ARVALIS* do not provide advisory organisations with the knowledge needed to provide such an adaptation. This may lead to further exclusion of small farms from group advice, where farmers compare field observations with their *FARMSTAR* maps. There are also difficulties associated with the development of *Phytnes*. As for *FARMSTAR*, the use of the DST requires the advisors to complete electronic forms about farms on a regular basis. This work has a fixed 'cost' per farm for the advisors, whether it is charged per hectare by InVIVO to the cooperative that is client of the service. This means that advisers have a disincentive to work with small farms using such software. Therefore, there could be some cumulative effects due to the exclusion of small farms. The fact that they are not integrated in the DST will mean that they might not have access to the same services as other farmers, but also that the database accumulated by collecting farmers' data through DSTs won't integrate small farm data, leading to a growing disconnection between this database and the knowledge needs of small farms.

9 References

Berriet-Solliec, M., Labarthe, P., Laurent, C. (2014) . Goals of evaluation and types of evidence. *Evaluation, The International Journal of Theory, Research and Practice*, 20(2): 195-213.

Borghoff, U. M., and Pareschi, R. (1997). Information technology for knowledge management. *Journal of Universal Computer Science*, 3(8), 835-842.

Browne, K. (2005). "Snowball sampling: using social networks to research non ‐ heterosexual women". *International Journal of Social Research Methodology*, 8 (1).

Carvalho, R., Baroni de & Ferreira, and Araújo Tavares M. (2001) "Using information technology to support knowledge conversion processes", *Information Research*, 7(1)

Cowan, R., and Gunby, P. (1996). Sprayed to death: path dependence, lock-in and pest control strategies. *The economic journal*, 1996: 521-542.

Gallouj, F., Rubalcaba, L., and Windrum, P. (Eds.). (2013). Public-Private Innovation Networks in Services. Edward Elgar Publishing.

FNLON (2009). Surveillance biologique du territoire : Synthèse sur l'inventaire des outils existants et leur caractérisation. Rapport CASDAR, 257 p. Available on line. http://agriculture.gouv.fr/IMG/pdf/20090612-Rapport_final_cle027311.pdf

Hill, P. (1999). Tangibles, intangibles and services: a new taxonomy for the classification of output. *Canadian journal of economics*, 1999: 426-446.

Labarthe, P. (2014). AKIS and advisory services in France. Report for the AKIS inventory (WP3) of the PRO AKIS project. Online resource: www.proakis.eu/publicationsandevents/pubs

Labarthe, P. (2009). Extension services and multifunctional agriculture. Lessons learnt from the French and Dutch contexts and approaches*. Journal of environmental management*, 90: 193-S202.

Labarthe, P., and Laurent, C. (2013). The Importance of the Back-office for Farm Advisory Services, *Eurochoices* 12(1): 21–26.

Labarthe, P., Gallouj, F., and Djellal, F. (2013). Effects of institutions on the integration of end-users' knowledge in ServPPINs: lessons from two case studies in agro-environmental knowledge-intensive services". In Gallouj F., Rubalcaba L., Windrum Paul (eds), Public–Private Innovation Networks in Services. (Cheltenham, UK: Edward Elgar Publishing, 2013), pp. 303-325.

Labarthe, P., and Laurent, C. (2013). Privatization of agricultural extension services in the EU: Towards a lack of adequate knowledge for small-scale farms? *Food Policy*, 38: 240–252.

Labarthe, P., Caggiano, M., Laurent, C., Faure, G., and Cerf, M., (with the collaboration of Cristovao A., Knierim A., Prager K., Sutherland L.A.) (2013).Concepts and theories available to describe the functioning and dynamics of agricultural advisory services. Learning for the inventory (PRO AKIS WP3), 2013.Deliverable 2.1 of the PRO AKIS FP7 EU Project. 21 p. + annexes.

Lundvall, B. Ä., and Johnson, B. (1994). The learning economy. *Journal of industry studies*, 1(2), 23-42.

Nonaka, I. (1994). A dynamic theory of organizational knowledge creation. *Organization science*, 5(1), 14-37.

Polanyi, M. (1967). The tacit dimension.

Poppe, K. J., Wolfert, S., Verdouw, C. and Verwaart, T. (2013). Information and Communication Technology as a Driver for Change in Agri-food Chains. *EuroChoices*, 12: 60–65.

Siggelkow, N. (2007). Persuasion with case studies. Academy of Management Journal, 50(1), 20-24.

Vanloqueren, G., and Baret, P. V. (2008). Why are ecological, low-input, multi-resistant wheat cultivars slow to develop commercially? A Belgian agricultural 'lock-in'case study. *Ecological Economics*, 66(2), 436-446.Vargas 2012

Wilson, C., and Tisdell, C. (2001). Why farmers continue to use pesticides despite environmental, health and sustainability costs. *Ecological economics*, 39(3), 449-462.

Yin, R. K. (1989). Case Study Research: Design and Methods. Sage Publications. London.

10 Appendices

10.1 Appendix 1. Additional information about methodology

Table 5. List of people interviewed (source: the authors)

Name	Organisation	Responsibility
Benjamin Mallavan	*Airbus* Industrie	Coordination of *Farmstar* service
Jean-Paul Bordes	*ARVALIS* (research institute)	Conception of *FARMSTAR*
Mathilde Closset	*ARVALIS* (research institute)	Conception of *Farmstar* model
Julien Charbonnaud	*CETIOM* (research institute)	Vaidation of the *Farmstar* model for rapeseed
Mickael Mimeau	Dijon Céréales (farmers' cooperative)	Diffusion and validation of *Farmstar*
Katia Gernigon	Axéréal (farmers' cooperative)	Diffusion of *Farmstar*
Hervé Pinel	Terrena (farmers' cooperative)	Director
xxxxx	Capseine	Diffusion of *Farmstar*
Yvon Lambert	Chambre d'agriculture de Bretagne	Diffusion of *Farmstar*
Odile Tauvel	Chambre d'agriculture de l'Eure	Diffusion of *Farmstar*
Thierry Darbin	InVIVO	Responsable Marketing, in charge of national diffusion of *Phytnes*
Katia Gernigon	InVIVO	Responsible for the development of *Phytnes*
Dominique Blancard	INRA	Phytopatologist. Creator of the *Di@gnoplant* DST.
xxxxx[18]	Société nationale d'horticulture française	Diversification of the *Di@gnoplant* DST
xxxxx	Fédération française des défenseurs de pommes de terre	Diversification of the *Di@gnoplant* DST
xxxxx	AIRINOV	Responsible of a DRONE application of *FARMSTAR*
xxxxx	Dijon céréales	Adviser using *FARMSTAR* and *Phytnes*
xxxxx	Axéral	Adviser using *FARMSTAR* and *Phytnes*

Presentation of the questionnaire

1- <u>Informations générales :</u>
Q1 : Nom de l'unité de la personne interviewée
Q2 : Localisation
Q3 : Position au sein de l'unité
Q4 : Objectifs spécifiques de l'unité

2- <u>Description du logiciel :</u>
Q5 : Pouvez-vous décrire le service en quelques mots ?
Q6 : Quels sont les objectifs de ce logiciel ?
Q7 : Quelle est la dimension environnementale ?
Q8 : Quels sont les supports du logiciel ?

3- <u>Stratégie économique</u>
Q9 : Comment le logiciel est diffusé chez les agriculteurs :

[18] We market with xxxxx the name of the people who wanted to stay anonymous.

*Est-ce qu'il est payant / gratuit ?
*Qui fait payer ces services ? A qui vont les bénéfices ?
Q10 : Quelques chiffres clés :
*Chiffre d'affaire du service
*Superficie concernée.
*Nombre d'exploitations équipées.
*Business plan pour les années à venir.

4- Dynamique de validation des modèles et des résultats :
Q11 : *Sur quels modèles agronomiques le service se base-t-il ?*
*Sur quels modèles les valeurs d'économies d'intrants azotées affichées sur le site sont-elles calculées.
Q12 : *Qui valide ces modèles agronomiques ?*
Q13 : Comment les prédictions sont-elles validées ?
*Par qui sont-elles validées ?
*Quelles sont les règles de validation ?
Q14 : *comment les effets sont-ils validés ?*
*Expérimentation en station ?
*En condition réelle chez les agriculteurs ?
*Quelles sont les méthodes statistiques qui permettent de sortir les différents chiffres d'économie d'intrant ?
Q15 : Quel est le rôle des différents acteurs dans la création et la validation de ces modèles ?
Q16 : Quelles sont les méthodes de préconisations ?
*Prise en compte ou non des reliquats d'azote ?
*Comment la performance prédictive est validée ?

5- Structure partenariale :
Q17 : Pouvez-vous faire un bref historique sur l'histoire partenariale du service?
Q18 : Pourquoi vous êtes-vous associés à ce service ?
Q19 : Quel est l'intérêt d'avoir choisi une dynamique s'ancrant dans ce partenariat (privé, public, public-privé) ?
*Quelles sont les stratégies économiques derrière ce partenariat ?
Q20 : Quel est le rôle des différents partenaires ? Quelles sont leurs fonctions ?
Q21 : Comment la recherche est impliquée autour de ce logiciel ?

6- Relations avec les instituts de conseils agricoles :
Q22 : Comment s'intègre les structures de conseil agricole autour du service ?
Q23 : Quel est leur(s) rôle(s) dans la diffusion de ce logiciel ?
Q24 : Sont-elles associées à des processus de validation ou de mise en conformité du service ?

7- Suivi des agriculteurs :
Q25 : Comment est organisé le retour des agriculteurs quant aux performances du service ?
*Les objectifs sont-ils atteints ?
*Qui est en charge de faire un suivi des performances du logiciel dans les exploitations ?
* Sur quelles méthodes est-il effectué ?
Q26 : Quelle est l'adaptation du service aux différents types d'exploitation et au choix des agriculteurs ?
*Quels sont les matériaux nécessaires à l'optimisation du service. (Exemple : différence de fonctionnement avec un GPS et sans GPS).
*Comment les conseils de fertilisation diffèrent en fonction de la taille des parcelles.
*Est-ce que le service est modulable à différents types d'exploitation (petites exploitations/ grandes exploitations/ Agriculture biologique) ?

10.2 Appendix 2. Presentation of the three DSTs

10.2.1 Description of *FARMSTAR*

Description : *Farmstar* is a service which has been made through a private-public partnership between the company *Airbus* and two technical institute: *Arvalis* and the *Cetiom*. With satellite images and techniques of biomasse measurement, this service is able to offer to farmers some advices about their fertilisation (on wheat, barley, triticale and rapeseed). It is also able to watch the heterogeneity on a same plot allowing farmers to modulate their fertilization.

Environmental purpose: *Farmstar*'s technology allow farmer to reduce their nitrogen inputs (20 to 30 kg per hectare and per an on rapeseed and 10 to 20 kg on wheat).

Research : *Arvalis* and the *Cetiom* (public instituts) bring agro-climatics models. *Airbus* is then in charge to translate this model in the data base. Both public institut check and adapt the service at some regional characteristics.

Diffusion : recommendation maps are sold to coopératives, Chambers of Agriculture and some private company who are in charge to sell it to farmers. The service cost to farmers between 10 and 15 euros per hectare.

The different steps of the software's operation are showing on the diagram one.

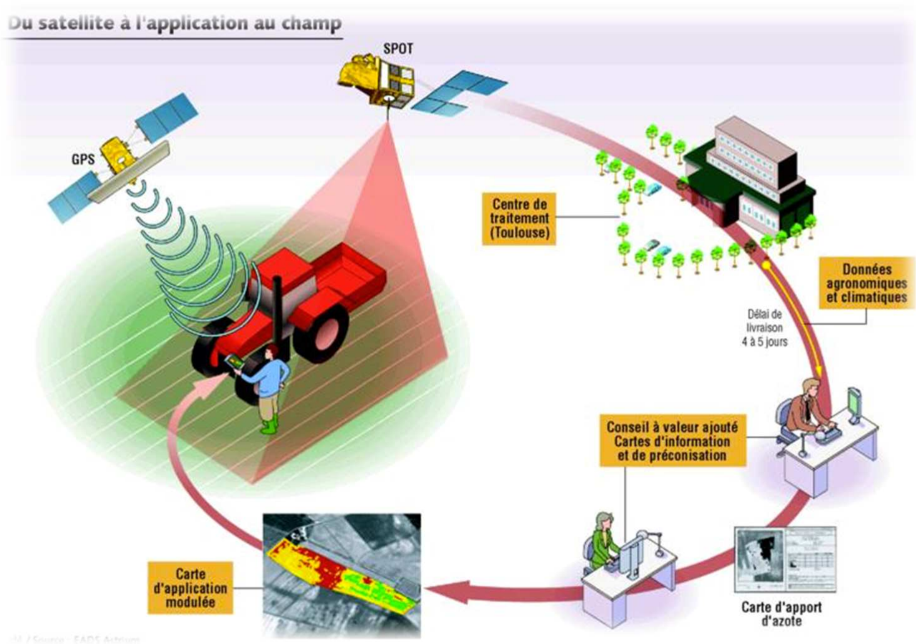


Figure 5. From satellite to field: the different steps of the FARMSTAR DST (source: ARVALIS)

The farmer can receive their advice on a paper or directly to their mail box. The maps are composed of comprehensive advice on the plot, but also contain more precise recommendations on different areas of the same plot. A colour gradient allows farmers to see the areas that need more or less nitrogen. They will receive three different maps at key moments of the year:

- A first map at the end of February which allows an estimate of nitrogen absorbed by the vegetation cover to be made and to calculate a total dose that the farmer will have to bring during his growing season.
- The second map is sent in mid-March. This map estimates the number of stems on the plot and suggests a potential return.
- The third map is send in the middle of May when the last leaf of the plant is out. It allows the suggestion of a last nitrogen dose to reach the potential return purpose.

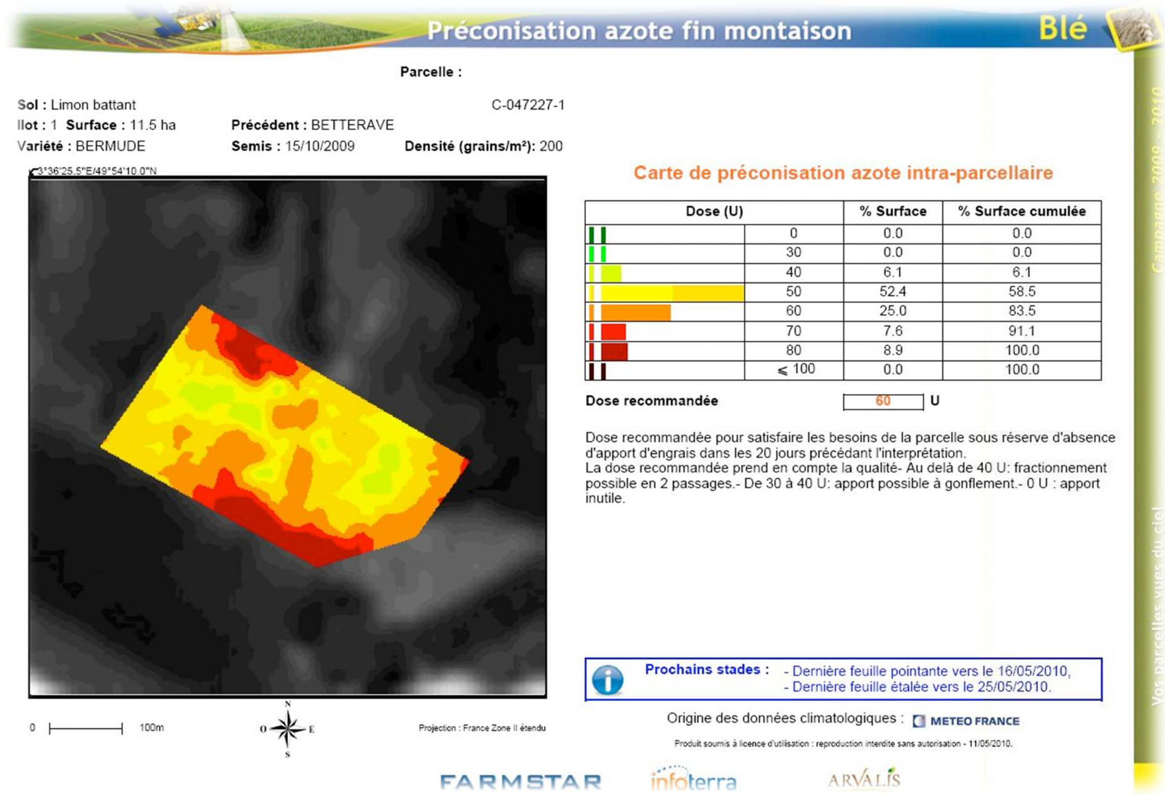


Figure 6. Example of *FARMSTAR* interface with a nitrogen map (source: *Arvalis*)

Farmstar satellites are now much better than the first one. Today, all of France is able to be covered by the service. The service is available today in more than 50 departments by thirty partners. In 2014, 661 000 hectares was covered by the *Farmstar*'s technology (380 000 on wheat, 205 000 on rapeseed, 72 000 on barley and 4000 on triticale).

Figure 7. National diffusion of FARMSTAR in 2013 (source: ARVALIS)

The outlook of the software is now in a logic of densification. In the covered areas, the economic strategy plans to increase the number of hectare affected every years. Some projects of diversification are also thinking of the software. *Airbus* also want to complete their service to offer better image, or with a cost less important in area with a high heterogeneity.

10.2.2 Description of *Di@gnoplant*

Description: *Di@gnoplant* is mobile software who was made by team in INRA Bordeaux. Linked at the server Ephytia, it allows doing a diagnosis with image of plants disease. Users can benefit of complete information about disease in their farm, and can read some recommendations about how to fight against. The software is linked to a website of the French Minister of Agriculture to have the list of every inputs available on the market. *Di@gnoplant* is today available on cultures of salad, tomatos, zucchini, tobacco, melon and vine.

Environmental purpose: This service allows the avoidance of intensive treatment because of a specific recommendation.

Research: Research behind this software comes from a public institutes, e.g. l'INRA. Dominique Blancard has integrated information about his expertise. Currently, INRA tries to establish partnerships with other institutes to diversify their software on other products.

Diffusion: *Di@gnoplant* is free. Users can download it on the Apple or Google store. However, INRA has not undertaken any survey about the diffusion of their software.

Support : To benefit of the software, users have to get a smartphone or a pad.

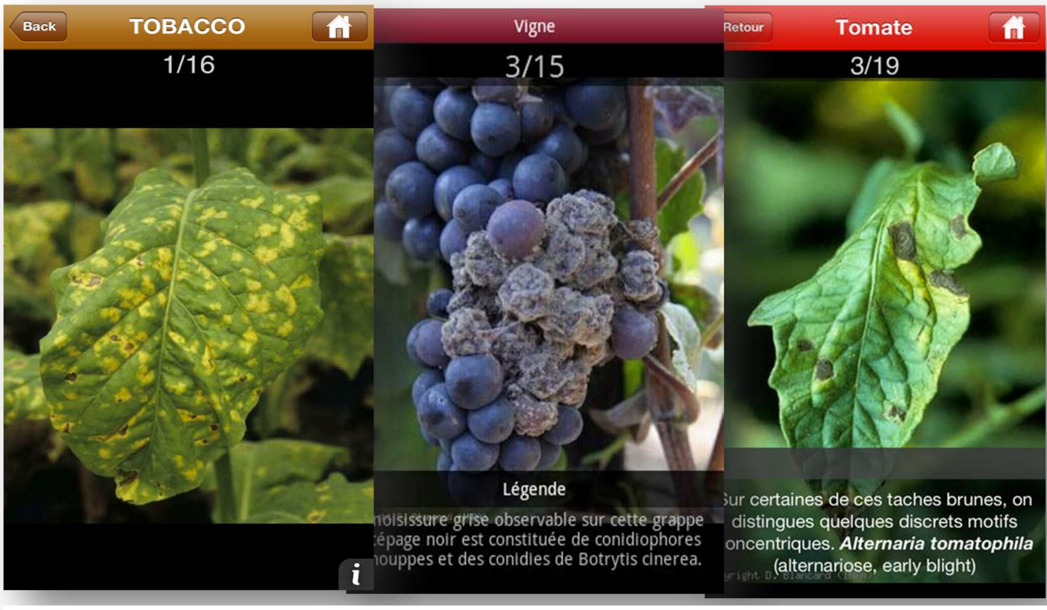


Figure 8. Examples of the pest picture library of Di@gnoplant (source : the authors)

INRA surveys 400 connections per day (90 000 per day) in their server Ephytia. We do not know how many applications have been downloaded with regard to sofware *Di@gnoplant*.

10.2.2 Description of *Phytnes*

Description : *Phytnes* is a software which has been created by Invivo's company for the agricultural adviser. From a complex interface, it allows to technician to optimize their advice. This software allows access to a big database about different agricultural topics (regulations, agricultural and geographical information, crop diseases, advice about inputs, etc.), but also to follow the customer's practices, make some balances sheets and recommendations, and to do a traceability or compare several solutions.

Environmental objectives: *Phytnes* has two interfaces: the first one is about intensive agriculture and the second one is ecological. According to the expectations of the farmer, the agricultural adviser can then choose the cover that best fits them, or combine information from both interfaces. In a general way, *Phytnes* is a supporting software which allows to optimize recommendations and to propose appropriate treatments.

Research : The software has been created by Invivo, who have their own research team. The information in the software also come from the same team. The database has been validated by Invivo company.

Diffusion : This software is for member cooperatives. Invivo sell this service to these cooperatives who are in charge of equipping their agricultural adviser. An interface allows the cooperative to put their own chemical products into the database. The software takes part of the global service of the company. Farmers don't have to pay to benefit the service.

Support : *Phytnes* takes the form of a classical software. Advisers can install it on their own computer.

Today the new software *Phytnes* 2 is much more complete and aesthetic than the first one. It involves 650 advisers and more than 900 000 hectare. Invivo has a target of 3 million of hectares involved in the service in next three years.