

Gouee, Patrick Le

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DEMETER: an original reasoning to assess and control the loss of agricultural land related to the urban sprawl.

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DEMETER: an original reasoning to assess and control the loss of agricultural land related to the urban sprawl.

Patrick Le Gouée¹

¹ Géophen Laboratory, UMR LETG 6554 CNRS, University of Caen, F-14032 Caen Cedex, France.

E-mail: Patrick.legouee@unicaen.fr

Abstract:

In the prolongation of the research actions relating to interregional program PSDR GO DYTEFORT, we have developed the program DÉMÉTER. This one is articulated around three objectives. At the level of the department of Calvados (5500 km²) and over one recent period (1998-2006), it is a question (1) of quantifying agricultural surfaces which have been consumed by the urban sprawl, (2) to identify for each of the 705 municipalities of the Calvados the sectors to preserve urban sprawl when those are characterized by soils with an agronomic strong potential, (3) to take the measurement of the environmental and economic consequences induced by the artificialisation of the soil resource.

The results of this study show that between 1998 and 2006, the Calvados has recorded a loss of agricultural areas related to the urban sprawl of about 5100 hectares. That represents the equivalent of the area of 7 municipalities of the department or 7285 football fields. 45% of urbanized areas have concerned soils with high agronomic potentiality. 16% of urbanized areas (850 ha) have involved the appearance of a high erosive risk. The cereal production loss in 2006 compared to 1998 has corresponded about 153,000 quintals and about 22,000 tons of dry matter for the fodder productions.

The restitution of the study near the territory agencies has led (1) on an awakening of the policy-makers to quickly mitigate the environmental and economic consequences of the urban sprawl, (2) to a wish to use the data of our study as a significant tool for the sustainable development in rural areas, (3) on the need for reinforcing the partnerships between the structures of research and the policy-makers.

Keywords: DEMETER, urban sprawl, agricultural land, sustainable development

Introduction

The project of framework directive on the soils protection (COM, 2006), adopted in first reading on November 14th, 2007 by the European deputies, testifies to the need for fighting against one of the principal threats: the artificialisation of the soils. This one originates in the urban sprawl. The development of transport networks, of industrial, commercial and residential areas, of services and entertaining, are done mainly with depend on the arable lands. The consequences of the urban sprawl on the soils are important. It causes the loss of function of regulation of meteoric water, the loss of the functions of purification-filtration, it reduces the space of life of many edaphic species and insulates those by splitting up the landscape. More still, it cancels the agricultural potential of the soils and reduces the food production capacity of the rural areas.

According to the report of the European Agency of the Environment drawn up for 23 country of the European Union (AEE, 2005), nearly 800,000 hectares of soils have been artificialized between 1990 and 2000, that corresponding to a growth of almost 7% of artificialized surfaces. According to this study, nearly 85% of the artificialized soils had a function of agricultural production before. In France, work of Laroche *et al.*, (2006) recalls that, according to Corine Land Cover, the artificialisation increased of almost 5% between 1990 and 2000. This growth is due mainly to the development of the industrial and commercial areas and occurs overall in periphery of the cities.

If the documents of planning integrate today information concerning the richness of the natural heritage or water quality, they only take very seldom counts the agronomic quality of the soils of it. However, in France, tools for town and country planning like SCOT, PLU, municipal development maps, agricultural and rural plan can call into question the management style of territories (urban, natural and rural areas). These tools can also lead to reorganizations of territories and dynamic news territorial affecting the agricultural use of the soils. Consequently, it is necessary to be able to bring to the managers and to decision makers of the territory of the elements of sensitizing on the question of the consumption of agricultural lands related to the urban sprawl. It is also essential to produce the new knowledge dedicated to the durable preservation of the arable lands with high agronomic value in the areas threatened by the soils artificialisation. It is what we did within the framework of the DÉMÉTER study for a whole French department. It is the Calvados,

department of the Basse-Normandie region. This research action is in the prolongation of the research actions relating to the French interregional program PSDR GO DYTEFORT (2009).

1. The DÉMÉTER study

At the regional level and on the basis of treatment of relative information to the notifications of sale, to the cadastral data and TERUTI and TERUTILUCAS data, the land management agency of the Basse-Normandie (SAFER) reveals that, from 1982 to 2004, urbanized surfaces increased by 40% and this, to the detriment of the arable lands. 50% of the surfaces consumed by the urban sprawl have been the fact of housing construction whereas the industrial and commercial needs and the needs for infrastructures respectively consumed 30% and 20% of the agricultural soils. It comes out finally from these treatments that, of 2000 to 2009, the Basse-Normandie lost 3% of its useful agricultural surface, that is to say a little less than 40,000 ha over 10 years.

These treatments give a general idea of the urban sprawl at the regional level. To go further in the comprehension of this phenomenon, we developed program DÉMÉTER (French acronym meaning geographical diagnosis and control of the urban sprawl in the rural areas) on the whole of the Calvados. This one is articulated around 3 objectives: 1° to draw up an inventory, over one recent period of about ten years, of the consumption of agricultural lands related to the urban sprawl, 2° to bring an original methodology and new knowledge to measure the agronomic and environmental consequences of the urban sprawl, 3° to propose a tool of decision-making aid as regards reasoned territorial management.

1.1. Methodology related to the objective 1

The diagnosis of the consumption of agricultural lands related to the urban sprawl has been carried out starting from an exhaustive work of photo-interpretation on the whole of the Calvados, which represents 5,500 km². This step allows us to identify the agricultural uses of the areas before urbanization which we have grouped together in 5 classes: crop, grassland, orchards, forest, fallow land. A similar work has been carried out in connection with the types of urbanization. This one refers 6 classes: dispersed individual housing, individual and semi-collective housing which are grouped, economic zone, entertainment area, infrastructure of

communication, unknown type (works in progress). The photo-interpretation has been the subject of a systematic validation starting from observations of the environment (Jouan, 2009) on a sampling representative of the various types evoked previously (Figure 1).



Figure 1. Validation of the photo-interpretation starting from observations of the environment (Jouan, 2009)

The diagnosis has been posed over the period 1998-2006. Indeed, the analysis of the French database SITADEL (municipal database concerning the urbanized areas and the numbers of residences built between 1990 and 2006) shows that in most 705 municipalities of this department, the period 1998-2006 corresponds to the installation of a first cycle of urbanization or a new phase of urbanization (Figure 2). In addition, we could profit from the access to the air photographs of the IGN (national geographical institute) for these two dates and for the whole of Calvados.

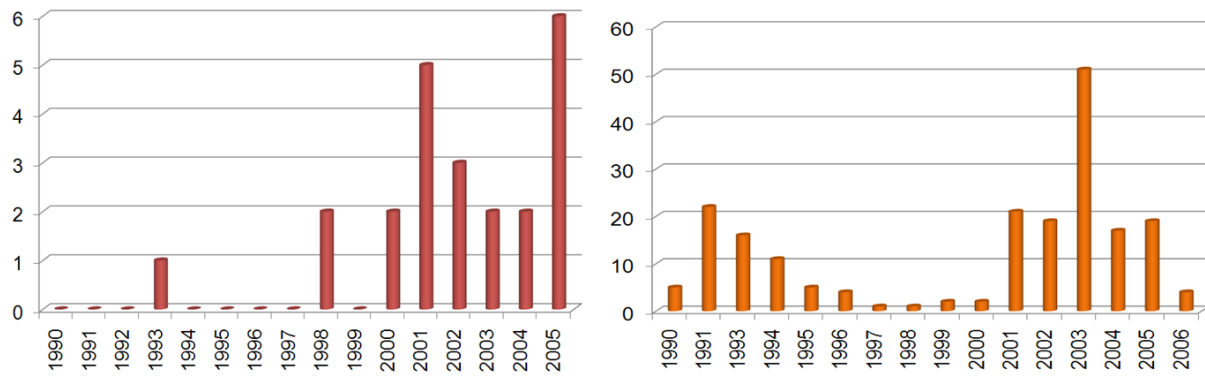


Figure 2. Main types of municipal urbanization for recent period.

All the data resulting from this work have been collected by means of a GIS which allows us to constitute a numerical and spatialized database and to produce maps relating to the urban sprawl at the same time exhaustive and with a high resolution.

1.2. Methodology related to the objective 2

The determination of the agronomic and environmental consequences of the recent urban sprawl in the Calvados has been related (1) on an evaluation of the quality of the arable lands which have been consumed and (2) to the soil erosion risk suitable for affect the new urbanized areas.

1.2.1. An essential precondition: the production of a soil map with fine spatial resolution

To lead this diagnosis to a spatial scale as fine as that of the identification of the urbanized areas between 1998 and 2006, it has been necessary to have as a preliminary a database about the soils with a high degree of accuracy. Very recently, the establishment of a soil map of the Calvados at fine scale (Le Gouée, 2008) and the publication of an exhaustive study on the soil erosion hazard (Le Gouée and Delahaye, 2010) constituted a very invaluable information sources. This mapping is based on some 7514 soil boreholes (approximately 1 soil borehole for 40 hectares of agricultural land), representing a thickness cumulated of more than 3500 meters and two years of work for three people. A typology of the soil boreholes has been allowed us to define 90 sites representative of the pedological diversity in the Calvados (Figure 3). Then, the takings carried out on these referents sites have been analyzed more precisely in laboratory in order to release the mean edaphic properties.

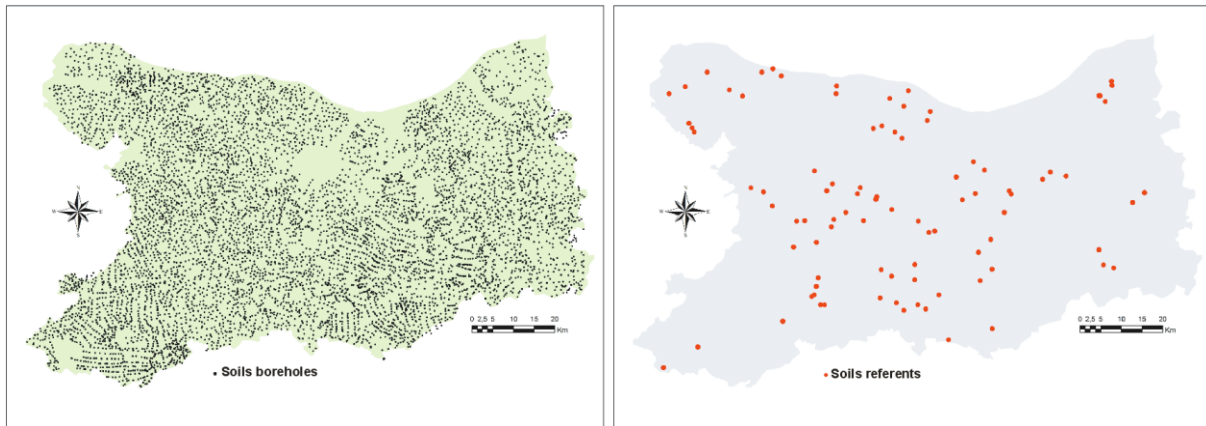


Figure 3. Positioning of the 7514 soil boreholes (on the left) and the 90 sites of reference (on the right) for the soil mapping.

After corrections of the soil boreholes database, a treatment by interpolation led to the development of the first map at scale 1: 25 000, then with the production of the final soil map at the scale 1: 50 000. The transfer of the soil boreholes data to a spatialized representation has been carried out by applying the fundamental concepts of mapping generalization: the concepts of lithological, topographical, chronological and biological sequences (Le gros, 1996).

1.2.2. The evaluation of the agricultural land quality

Concerning the agronomic consequences of the urban sprawl, the soil database of the Calvados has been used to develop model NGQS (French acronym which meaning global value of agricultural soil quality, Figure 4). This one allows us to appreciate the potential of agricultural production of the soils starting from edaphic factors (depth and texture), topographic factor (slopes) and pedo-climatic factor (hydrous stress). For each factor, one defines a value of quality (NQ) by associating with each of the 6 methods a value going of 1 (very low quality) in 6 (excellent quality). The summation of the values then their classification results in defining the NGQS. This value can be lowered by affecting points of penalty when the soil presents a stony load and/or a hydromorphy. By saying experts, it is then possible to connect the NGQS with agricultural potentials of production concerning of the cereal and fodder yields (fodder cultures and pastures).

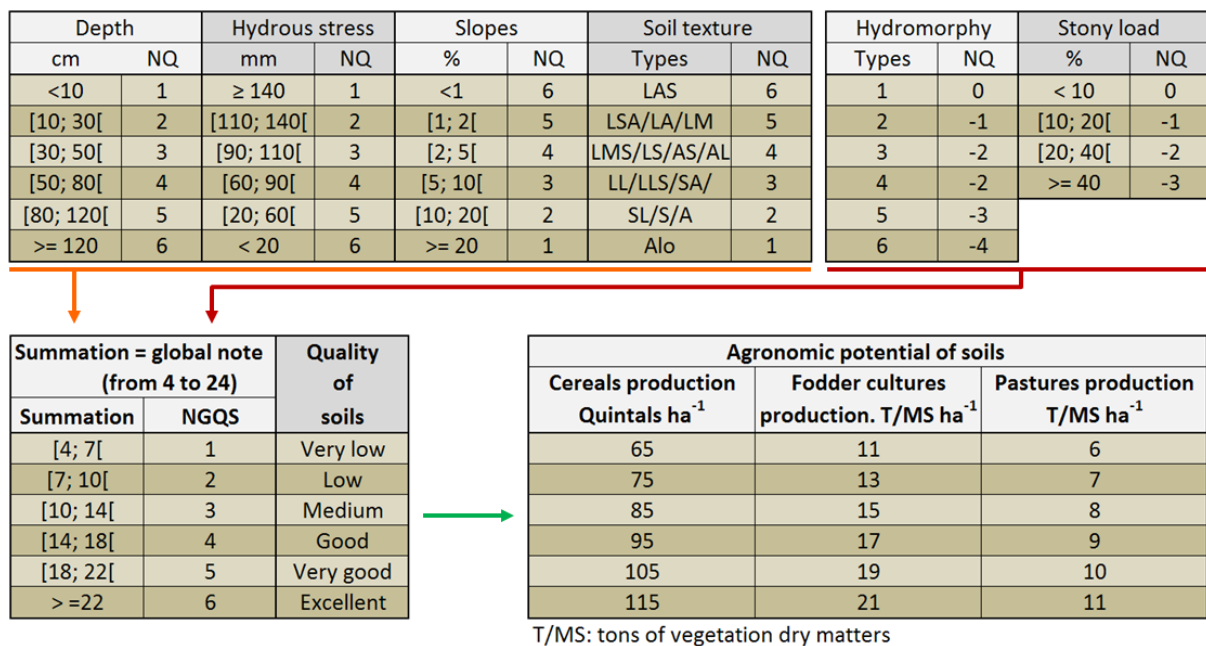


Figure 4. Structuration of the NGQS model.

By superimposing the areas consumed with the NGQS of the soils of the Calvados, we can then assess the agricultural soils quality which have been consumed and estimate, in 2006 compared to 1998, the potential loss of agricultural production of the urbanized soils while being equivalent quintals cereal and being equivalent tons of vegetation dry matter (fodder cultures and pastures).

1.2.3. The evaluation of the environmental consequences: the soil erosion risk

Concerning the environmental consequences, a preliminary work (Le Gouée *et al.*, 2010) managed to produce a map of the soil erosion hazard for the Calvados, at the agricultural parcel scale. By means of a GIS, we could assign to each urbanized area between 1998 and 2006 a level of soil erosion risk. For that, we have been allotted to them the strongest value of the erosion risk of the agricultural parcel located uphill slope and being at less than 20 meters of the urbanized area (Figure 5). The work of identification of the hydrological obstacles between the urbanized areas and the agricultural parcels located uphill slope not being possible currently at the department level, the evaluation of the risk has been undertaken in the mind of always possible hydrological connections between parcels and urbanized areas. Consequently, it is about an approach has maximum risk of erosion.

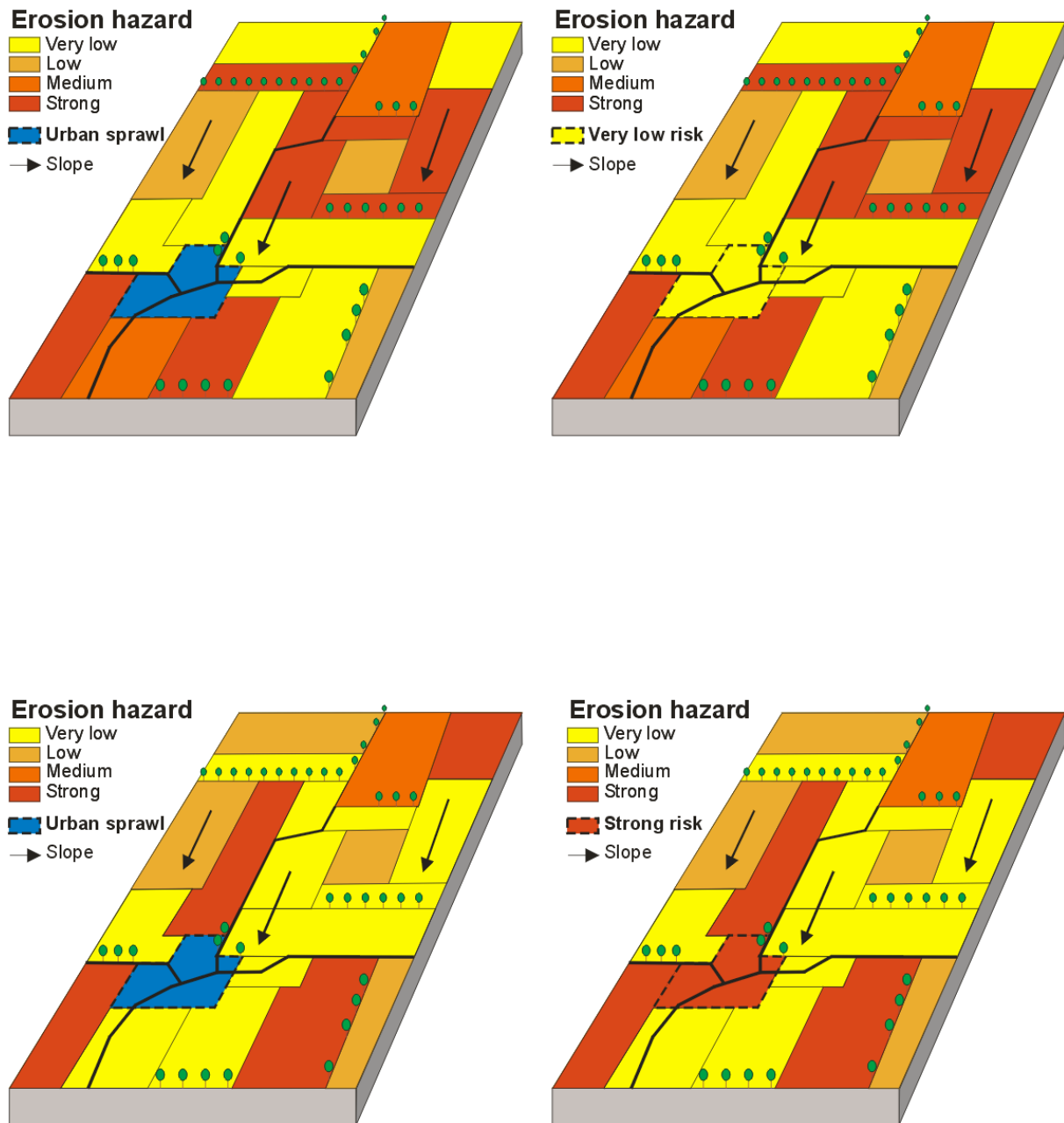


Figure 5. The evaluation of the environmental consequences: the soil erosion risk

1.3. Methodology related to the objective 3

Because of the high level of spatial resolution of the databases relating to the lately urbanized zones, to the NGQS values and to the levels of soil erosion risk, we can propose a tool of decision-making aid concerning the creation or the revision of town planning documents at the level of the communal development maps, the PLU or the SCOT. This one rests on mapping productions allowing us to (1) locate the agricultural parcels characterized by soils

with a strong agronomic potential and with a strong level of soil erosion risk erosion and to (2) cross these information with the zones intended for the urbanization in the near future (Figure 6). These data are accessible for each of the 705 municipalities and permit to the environmental managers to refine if necessary the arbitrations in connection with the sectors to be urbanized and to the methods of this urbanization. These new elements must be able to guide with more relevance the arbitrations to come related to the agricultural zones to urbanize by integrating in the reflections the preservation of the best arable lands and the protection of the future urban infrastructures.

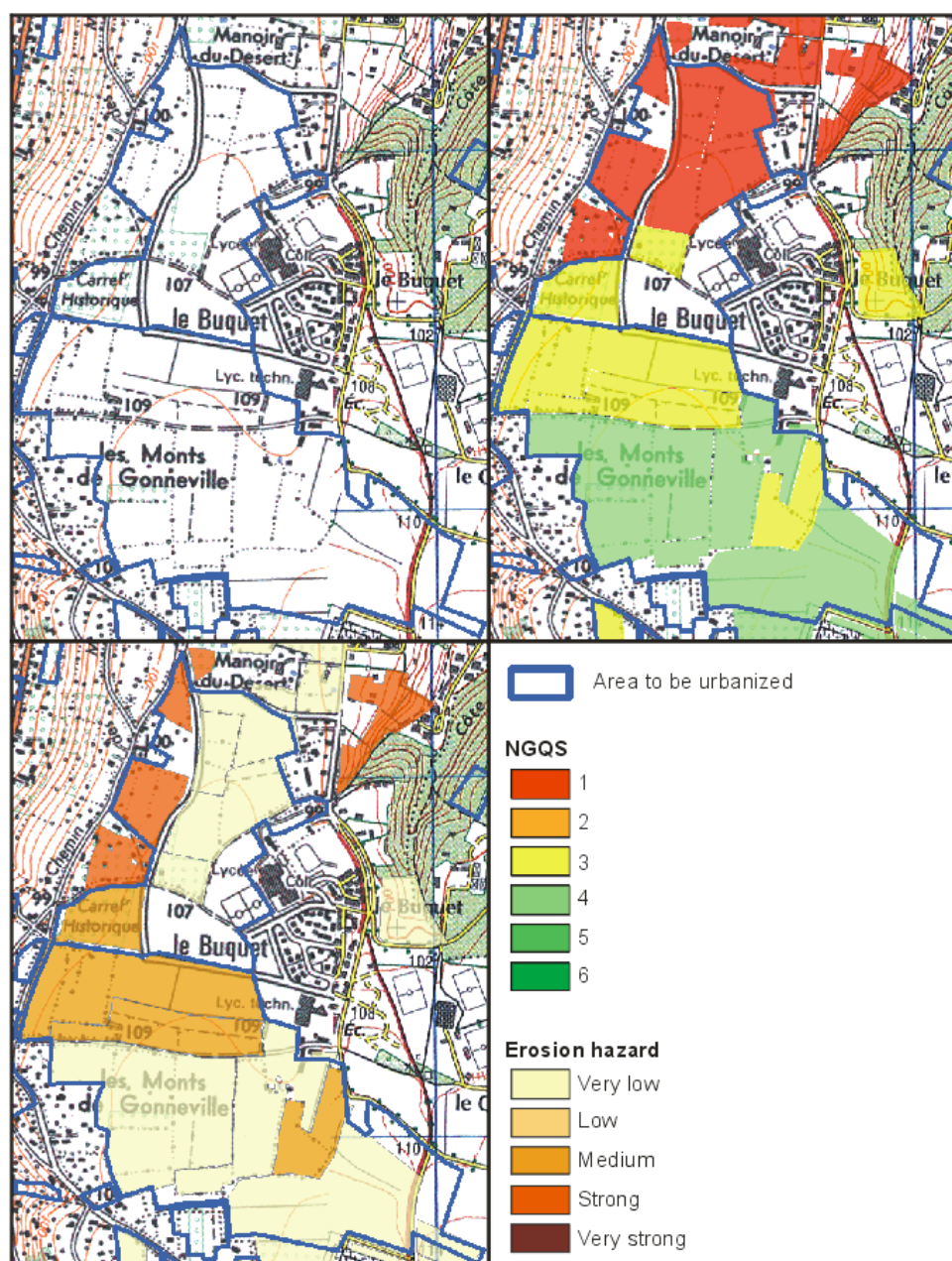


Figure 6. Areas to be urbanized and Déméter values concerning the NGQS database and the soil erosion hazard database.

2. Results

2.1. The urban sprawl

Between 1998 and 2006, the urban sprawl in the Calvados consumed a little more than 5100 ha of arable lands, which represents the equivalent of the surface of 7 municipalities of the department, 7285 football fields or the surface of a 500 km long motorway (Figure 7). The urbanization occurred with the detriment mainly grasslands (2940 ha consumed) and crops (1692 ha). The dispersed individual housing, the individual and semi-collective housing which are grouped and the economic zones respectively consumed 28%, 25% and 23% of the urbanized arable lands.

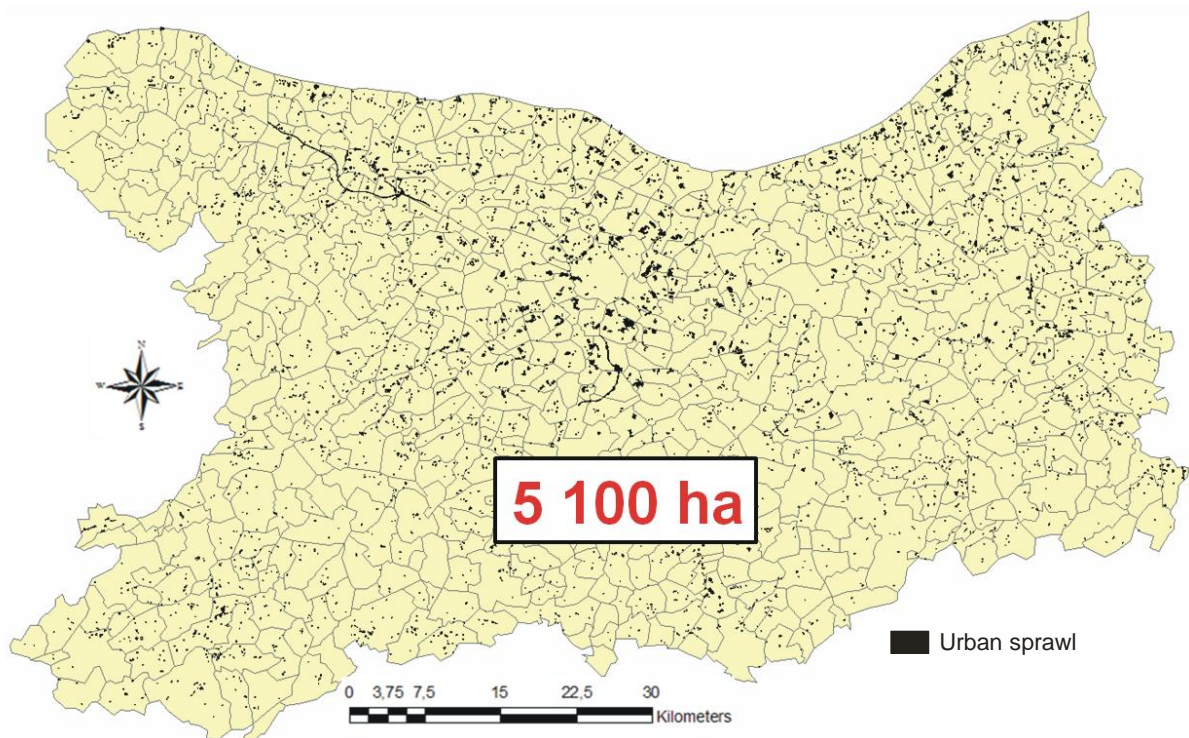


Figure 7. The urban sprawl in the Calvados Between 1998 and 2006.

Between 1998 and 2006, the urban sprawl represented on average an artificialisation of the soils about 1% of the Calvados territory. This value masks actually a spatial heterogeneity of the results. Thus, certain municipalities have been not concerned with the urban sprawl when others have been recorded an increase of more 4% of the artificialisation of the arable lands (Figure 8). The most significant urban sprawl has been concentrated around the main urban centre of the department on the level of the inner and outer suburb, along the main road ways and in the sector of the attractive coastal.

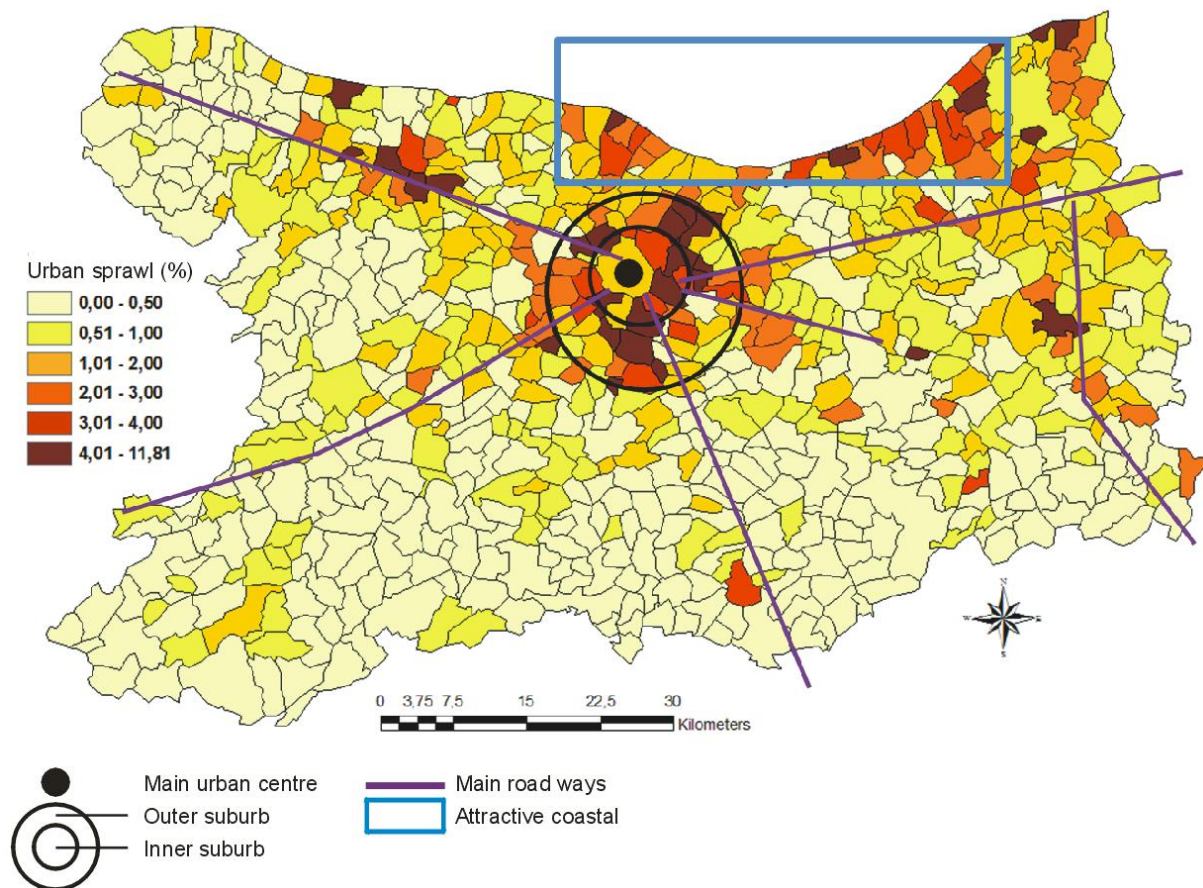


Figure 8. Urban sprawl at the municipality scale.

2.2. Agronomic and environmental consequences of the urban sprawl.

The application of NGQS model shows that the Calvados is characterized by arable lands of quality very heterogeneous (Figure 9). The soils of good quality ($NGQS > 3$) do not cover more than 1400 km² corresponds to 38% of the totality of the arable lands. Among those, very good agricultural soils ($NGQS > 4$) are marginal since they represent for only 15% of the arable lands. The mapping of the NGQS shows that the oriental sector of the department gathers mainly the soils with low quality whereas the center-north part joins together the soils of excellent quality (cf fig.).

The estimate of the quality of the consumed soils by the urban sprawl shows that 45% of lost agricultural surfaces have been characterized by a good quality ($NGQS > 3$) and 22% by an very good quality ($NGQS > 4$). One notes that good and very good arable lands have been consumed by the urban sprawl proportionally than the soils of less quality. In 2006, the potential loss of cereal production rose with 153,000 quintals compared to 1998, which

represents nearly 2% of the average cereal production of the department. The production losses in fodder (cultures and pastures) reached 22,000 tons of vegetation dry matter. The protection of the soils with strong agronomic value thus seems a true need.

Lastly, the urban sprawl has been generated an increase of 850 ha of the urban surfaces presenting a high level of soil erosion risk.

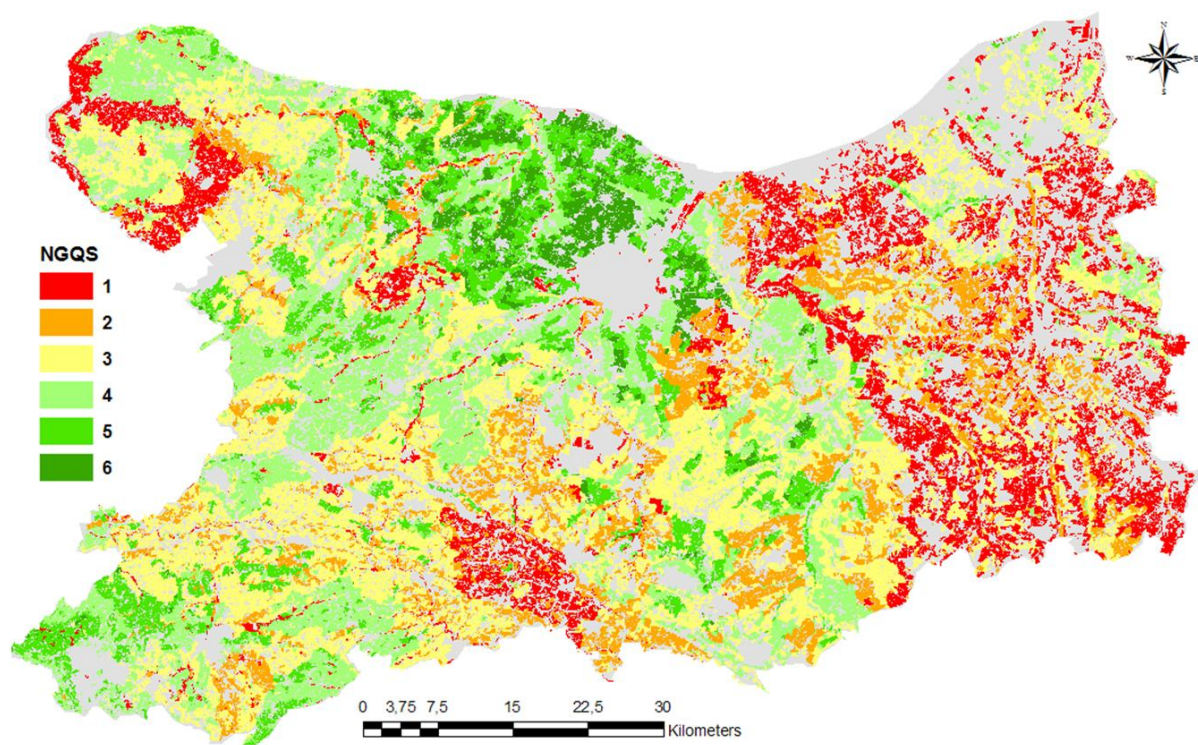


Figure 9. The NGQS values for the Calvados

The cases of the municipalities of Troarn (Figure 10, on the left) and of Périers-sur-le-Dan (Figure 10, on the right.) show that the NGQS database and the soil erosion risk database can help the managers of the territory to better conceiving the arbitrations as regards town planning.

The example of Troarn shows that the soils consumed between 1998 and 2006 have been characterized as being good arable lands (NGQS = 4). The characterization of the agronomic quality of the soils for this territory shows that in fact systematically the best soils have been consumed. The knowledge of the diversity of the agronomic quality of the soils on this municipality can lead to arbitrations henceforth supporting the preservation of these good soils.

The example of Périers-sur-le-Dan translates a context of environmental pressure high on the urbanized areas related to soil erosion. Indeed, the majority of agricultural surfaces located uphill slope urbanized areas have a very strong level of soil erosion risk. Consequently, the urban sprawl which developed between 1998 and 2006 in this municipality have been generated the appearance of a vulnerability of these urban infrastructures. The production and the provision of the soil erosion risk data allow us to direct the urbanization towards sectors with null or low risk and/or to mobilize the farmers to adopt practices of lowering of the levels of erosion risk.

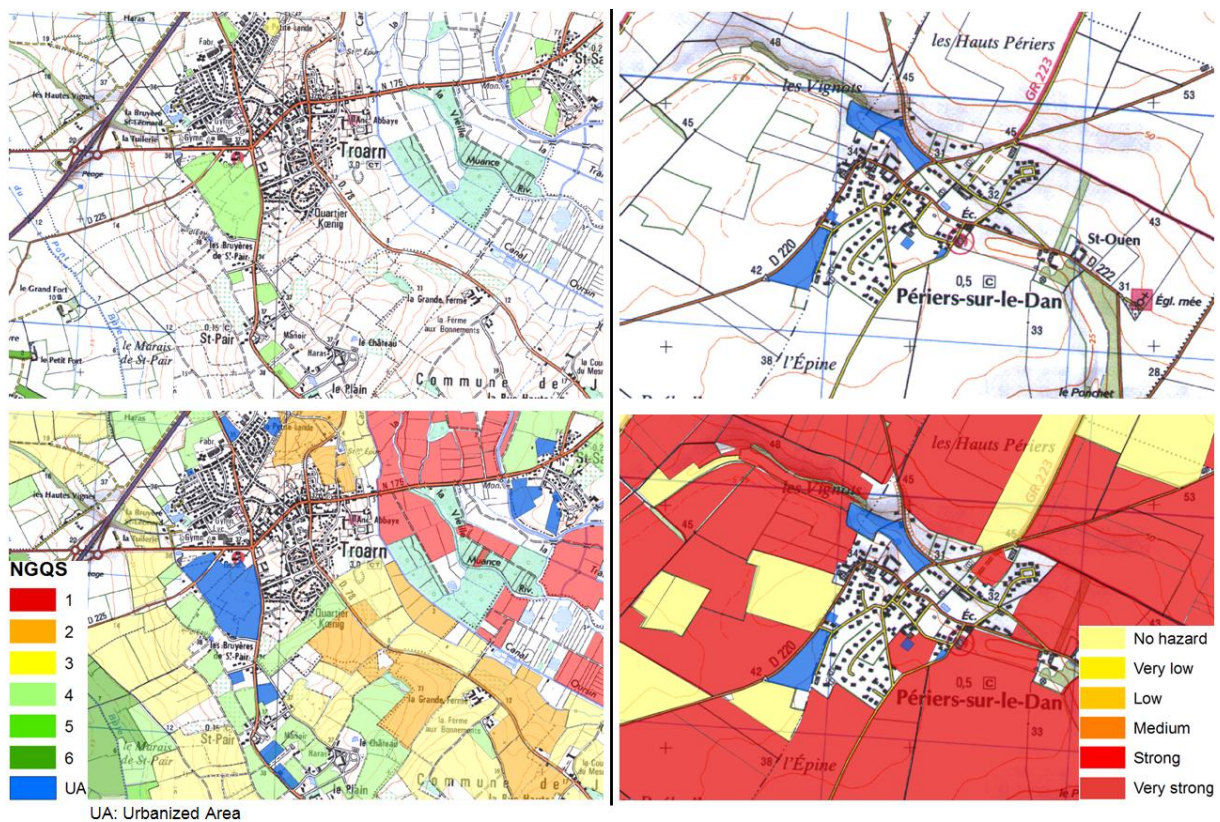


Figure 10. On the left, urbanized area and NGQS values for the municipality of Troarn. On the right, urbanized area and levels of the soil erosion hazard for the municipality of Périers-sur-le-Dan. Agricultural parcel scale.

3. Discussion

The evaluation of the urban sprawl by means of the photo-interpretation proves very relevant when one plans to precisely locate the urbanized areas and when one wishes to identify the old agricultural uses and the new urban methods. The checking of the work of photo-

interpretation by regular observations of the environment allows us to reduce the mistakes in interpretation and to obtain a reading of quality of the air photographs. However, this step carried out on 5500 km² represents six months of work for a person. Also, we currently study the possibilities of substitution of the photo-interpretation by the use of the teledetection. A comparative analysis of the results obtained by reading of air photographs and image processing SPOT 4 and 5 with spectral high-resolution is currently carried out near 3 zones characterized by agrarian contexts and methods of urbanization representative of the great majority of the agricultural and urban contexts of the Calvados. If the teledetection proves to be reliable, we in the long term plan to develop an observatory of the urban sprawl at the regional scale of the Basse-Normandie.

The estimate of the arable lands quality starting from NGQS model lies within the scope of an original step having for aim to preserve the best agricultural soils of the urbanization. The stakes are very important as well at the local and global levels.

At the local level, the preservation of the very good soils is a guarantee for the farmers of always being able to have the soils with high potential of production. That resulted in ensuring of the productions considered by the farmer as sources of income. This report is all the more important as it represents one of the basic elements in the continuity of the farms. Indeed, the durability of the exploitations of the Basse-Normandie answers the double need for the exploitations for being able to increase and to ensure the economic conditions of their transmission. In both cases, the possession and the possibilities of acquisition of very good soils are factors of this durability.

At the global level, if the artificialisation of the soils had continued in the next decades on a sustained rhythm such as it is observed in Europe for twenty years, it would become increasingly difficult to maintain and more further to increase the agricultural productions. If, as the example of the Calvados, it proves that in Europe, in fact mainly the soils with a strong potential of production are used by the urban sprawl, one can have to doubt the capacity of food self-sufficiency of the European countries in the medium and long term.

In front of these stakes, it appears absolutely necessary to quickly produce knowledge relating on the soils and their agronomic quality. In that, NGQS model proves to be interesting. To make sure of its robustness, we have been tested it near farmers in various pedological, topographic and agricultural contexts of the Calvados. It arises that this model has a very high reliability in connection with the characterization at the parcel scale of the agricultural quality

of the soils and about the estimate of the potentials of yields for the cereal and fodder cultures. However, of the improvements seem necessary to distinguish for the same soils, the more productive soils in Southern exposure of the less productive soils in Northern exposure. In addition, NGQS model appears less relevant to characterize various qualities of soils used for the pasture. A reflection must be carried out soon in order to identify the mean factors of production of the pastures.

The figures presented previously show how much it is essential to lay out of reliable information and with a high level of resolution to propose a tool of decision-making aid as regards installation of the territory in the rural areas. However, the appropriation of the step and the results of DÉMÉTER by the territory agencies suppose to propose a methodology which must be tested by external validations and to provide some databases at fine scale which correspond to a perceptible reality at the level of the people. The research process which allows us to answer that for some environments of several thousands of km² requires a very important investment and over several years. Perhaps would it be necessary to limit the sectors of investigation? In this case, we would deprive ourselves of the possibility of mobilizing the greatest number of managers acting from the municipality the level to the regional level. Perhaps would it be necessary to lower the level of spatial resolution of information? In this case, the dimension very applied of the results of research would be strongly compromised. The scientific argumentation to reduce the agronomic and environmental impacts of the urban sprawl would have a range very limited to all the decisional levels of the territory. We consider that this kind of approach should be encouraged because it is at the land registry scale that the arbitrations are made in the selection or the revision of the zones to be urbanized.

The DÉMÉTER step is included today in other French regions (Bretagne, Haute-Normandie). We are confronted with the difficulty in being able to ensure the optimum conditions for total appropriation of the step by the interested territorial agencies. There are two reasons which explain this difficulty.

On the one hand, we never considered at the beginning that there would be a methodological will of appropriation by the managers. The methodological choices retained by the researcher never took account of this kind of valorization. To answer this waiting, it would be necessary to propose a rather long specific training in which the researcher cannot invest himself because that does not concern its mission for which it is evaluated.

On the other hand, the DÉMÉTER step is based on theoretical knowledge and technical skills multidisciplinary which the researcher knew to mobilize but that it is very difficult to find in the interested territorial agencies.

To cure these obstacles, one could plan to assign with the researcher the mission of formation to the methods and the tools of research near the territorial managers and/or to devote a significant share of the instructions of the professional formations to the researchers developing of the research actions applied and innovating answering of the territory managers waitings.

Conclusion

Since twenty years in Europe, the urban sprawl has generated an artificialisation of the soils which cannot then any more provide their ecological, hydrological and agronomic functions. In France, the control of the urban sprawl and the attenuation of its impacts on the environment depend mainly on the creation or the revision of planning documents taking of account the agronomic and environmental characteristics on the spatial scales finest. Consequently, it is essential to produce new knowledge with spatial high-resolution dedicated to durable preservation of the soils as an environmental resource and as support of the agricultural productions when its agronomic value is high. It is what we have done within the scope of the DÉMÉTER study for a whole French department.

This one is articulated around 3 objectives: 1° to draw up an inventory, over one recent period of about ten years, of the consumption of agricultural lands related to the urban sprawl, 2° to bring an original methodology and new knowledge to measure the agronomic and environmental consequences of the urban sprawl, 3° to propose a tool of decision-making aid as regards reasoned territorial management.

Between 1998 and 2006, the urban sprawl in the Calvados consumed a little more than 5100 ha of arable lands, which represents the equivalent of the surface of 7 municipalities of the department, 7285 football fields or the surface of a 500 km long motorway. The estimate of the quality of the consumed soils by the urban sprawl shows that 45% of lost agricultural surfaces have been characterized by a good quality (NGQS>3) and 22% by an very good quality (NGQS>4). In 2006, the potential loss of cereal production rose with 153,000 quintals

compared to 1998, which represents nearly 2% of the average cereal production of the department. The production losses in fodder (cultures and pastures) reached 22,000 tons of vegetation dry matter. Moreover, the urban sprawl has been generated an increase of 850 ha of the urban surfaces presenting a high level of soil erosion risk.

The cases of the municipalities of Troarn (Figure 4, on the left) and of Périers-sur-le-Dan (Figure 4, on the right.) show that the NGQS database and the soil erosion risk database can help the managers of the territory to better conceiving the arbitrations as regards town planning.

The evaluation of the urban sprawl by means of the photo-interpretation proves very relevant. However, this step carried out on 5500 km² represents a considerable working time. Also, we currently study the possibilities of substitution of the photo-interpretation by the use of the teledetection.

The estimate of the arable lands quality starting from NGQS model lies within the scope of an original step having for aim to preserve the best agricultural soils of the urbanization. Also, the NGQS model proves to be interesting. To make sure of its robustness, we have been tested it near farmers in various pedological, topographic and agricultural contexts of the Calvados. It arises that this model has a very high reliability.

The figures presented previously show how much it is essential to lay out of reliable information and with a high level of resolution to propose a tool of decision-making aid as regards installation of the territory in the rural areas. We consider that this kind of approach should be encouraged because it is at the land registry scale that the arbitrations are made in the selection or the revision of the zones to be urbanized.

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