Integrating ecosystem services and multifunctionality for preservation of peri-urban agricultural lands

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Integrating Ecosystem Services and Multifunctionality for Preservation of Peri-Urban Agricultural Lands: Multi-level Analysis in the case of the Ile-de-France Region

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Résumé

L'intégration des Services Écosystémiques et de la Multifonctionnalité pour la préservation des terres agricoles péri-urbaines: analyse multi-scalaire dans le cas de la région Ile-de-France

L'agriculture périurbaine doit faire face au grand défi de l'extension urbaine et de l'expansion des espaces naturels et de loisirs à proximité des villes. La Multifonctionnalité de cette agriculture (AMF) et les services écosystémiques (ES) sont deux stratégies qui reconnaissent et gèrent plusieurs services et disservices de l'agriculture, au-delà de la production de la nourriture et de matières premières. AMF et ES sont des concepts étroitement liés et très complémentaires. Chacun a ses avantages et aussi ses lacunes. Cependant, les deux communautés qui portent ces concepts ont entre elles peu d' interactions et des échanges limités.

L'objectif de la thèse est de contribuer à des approches intégrées de l'AMF et ES pour la recherche agricole périurbaine. Le présent mémoire (i) développe un cadre intégré des ES et de l'AMF pour l'agriculture péri-urbaine, cadre basé sur une étude comparative des travaux de recherche en agriculture portant sur chacun de ces concepts et montrant son application dans le cas de l'agriculture de la Région Ile-de-France, (ii) démontre aussi comment l'approche intégrée de l'AMF et des ES fonctionne sur des problèmes concrets liés à l'agriculture péri-urbaine, sur la base de deux études approfondies portant l'une sur la gestion des terres agricoles abandonnées et l'autre sur le recyclage agricole des déchets urbains en Ile-de -France. Des analyses multi-échelles (de la région, voire du national, au petit territoire) ont été réalisées pour ces deux thématiques.

Le cadre intégré des ES et de l'AMF pour l'agriculture péri-urbaine distingue quatre catégories de combinaisons ES / fonction : (i) une fondée sur le service d'approvisionnement et ses fonctions connexes, (ii) une autre sur les services d'aménités paysagères et culturelles et les fonctions connexes (iii) une troisième portant sur le recyclage agricole des déchets urbains, comportant les services d'absorption des déchets urbains et de fertilisation des terres agricoles (iv) enfin les fonctions environnementales, qui caractérisent les contributions des agriculteurs au maintien de multiples ES de régulation et de soutien pour les agro-écosystèmes et les systèmes semi-naturels environnants.

L'étude approfondie de la gestion des terres agricoles abandonnées identifie que cet abandon des terres dans les zones urbaines est particulièrement lié aux « villes nouvelles » et à l'aéroport Roissy Charles-de-Gaulle. En zone rurale, la cause principale de l'abandon est généralement liée à des qualités agronomiques médiocres. Les perceptions des acteurs locaux concernant les ES et les disservices portés par les terres agricoles abandonnées diffèrent avec la zone géographique et l'échelle. Les acteurs préfèrent une stratégie AMF pour la réutilisation des terres agricoles abandonnées.

La deuxième étude approfondie montre l'inadéquation spatiale entre la production des boues d'épuration urbaines et la distribution des terres agricoles susceptibles de les recevoir. L'épandage des boues d'épuration franciliennes s'éloigne de fait de la zone péri-urbaine, au moins dans la partie occidentale de l'Ile-de-France. Au contraire, le compost de déchets verts est devenu de plus en plus apprécié des agriculteurs. On propose un cadre d'analyse des influences des échelles spatiales sur la relation offre-demande en ce qui concerne les déchets urbains, suivie d'une classification des agriculteurs en sept catégories concernant la perception et l'utilisation des déchets urbains dans leurs exploitations.

Le cadre intégré des ES et de l'AMF, et l'approche multi-échelle dans les études approfondies pourrait être intéressant pour des applications dans d'autres conditions. Des comparaisons à l'avenir entre les différents pays aideront à comprendre les différences et les points communs dans le classement de l'importance des différentes fonctions des agricultures péri-urbaines et devraient conduire à des instruments efficaces pour la préservation de l'agriculture péri-urbaine.

Mots clés : Services Écosystémiques, Multifonctionnalité, agriculture périurbaine, changement d'occupation du sol, multi-scalaire, Ile-de-France

Abstract

Integrating Ecosystem Services and Multifunctionality for Preservation of Peri-Urban Agricultural Lands: Multi-level Analysis in the case of the Ile-de-France Region

Peri-urban agriculture is in great challenge because of the pressure from urban extension or the expansion of natural and recreational spaces. Multifunctional Agriculture (MFA) and Ecosystem Services (ES) are two strategies that recognize and manage multiple services and disservices from agriculture beyond food and material production. MFA and ES are closely related and highly complementary. Each has advantages and also shortcomings. However, the two communities have limited interaction and exchange.

The objective of the dissertation is to contribute to integrated approaches of MFA and ES for peri-urban agricultural research. It (i) develops an integrated framework of ES and MFA for peri-urban agriculture based upon a comparative review on agricultural research working on the two strategies and application in the Region of Ile-de-France, (ii) and also demonstrates how the integrated approach of MFA and ES works on concrete problems linked to peri-urban agriculture with two in-depth studies on management of abandoned farmlands and agricultural recycling of urban wastes in Ile-de-France Region, respectively. Multi-scale analyzes were carried out for the two in-depth studies.

The integrated framework of ES and MFA for peri-urban agriculture distinguishes four categories of ES/function combinations: (i) includes provisioning ES and related functions.(ii) landscape amenity and cultural ES and related functions. (iii) agricultural recycling of urban wastes and the underpinning ES of waste breaking down and fertilization. (iv) environmental functions, which characterize the contributions of farmers to the maintaining of multiple regulating and supporting ES in agro-ecosystem and surrounding semi-natural habitats.

The in-depth study about management of abandoned farmlands identifies that land abandonment in urban area is especially linked to the New Towns and the pole of Airport Charles-de-Gaulle. In rural area, the reason is usually linked to poor agronomical conditions. Perceptions of local actors of ES and disservices of abandoned farmlands differ with the geographical area and scale. The actors prefer a MFA strategy for the reuse of abandoned farmlands.

The second in-depth study finds out that the production of sewage sludge spatially mismatches with the distribution of agricultural lands. Land application of sewage sludge is withdrawing from the peri-urban area in the western part of Ile-de-France. Contrarily, green waste compost is becoming popular. A framework concludes the multiscale influences on the supply-demand relationship regarding urban wastes, followed by a classification of seven categories of farmers.

The integrated framework of ES and MFA, and the multi-scale approach for in-depth studies will be interesting for application in other conditions. Comparison between different countries will help to understand the differences and common points in ranking the importance of different functions and formulate efficient instruments for the preservation of peri-urban agriculture.

Keywords : Ecosystem Service, Multifunctionality, peri-urban agriculture, land use change, multi-scale, Ile-de-France

Contents

List of abbreviations

AEM: Agri-Environment Measures

AEV: Agence des espaces verts, Agency of Green Spaces

AMAP : Association pour le Maintien d'une Agriculture Paysanne, Associations for the Preservation of Peasant Agriculture

CAD: Contrat d'Agriculture Durable, Contract of Sustainable Agriculture

CAP: Common Agricultural Policies

COP : cereal crops, oilseeds and protein crops

CTE: Contrats Territoriaux d'Exploitation, Farming Territorial Contract

ES: Ecosystem Services

Green Belt : Ceinture Verte

IAURIF: Institut d'Aménagement et d'Urbanisme d'Ile-de-France, Institute of Management and Urbanism of Ile-de-France Region

IGN: Institut Géographique National, National Geography Institute of France

LOA: Loi d'Orientation Agricole, Agricultural Orientation law

MEDDE: Ministère de l'Ecologie, du Développement durable et de l'Energie, Ministry of Ecology, Sustainable Development and Energy

MFA: Multifunctional Agriculture

MOS: Mode d'occupation du sol, Land Use Database of IAURIF

New Towns : Villes Nouvelles

OIN : Opérations d'Intérêt National, Operations of National Interest

PES: Payments for Ecosystem Services/Environmental Services

PREDMA: Plan régional d'élimination des déchets, Regional Plan for Elimination of Household and Similar Wastes

Régions Agricoles: Farming Regions

RGA: Recensement Général Agricole, General agricultural census

SAA: Statistic Agricole Annuel, Annual agricultural statistics

SAU: Surface Agricole Utile, Utilized agricultural land

SIAAP : Syndicat Interdépartemental pour l'Assainissement de l'Agglomération Parisienne

SRCE: Schéma Régional de Cohérence Ecologique, Regional Ecological Coherence Scheme

Trame Verte et Bleue: Green and Blue Networks

ZAC : Zone d'Aménagement concerté

ZUP: Zone à Urbaniser en Priorité, Areas to be Urbanized in Priority

General introduction

1. Challenge of peri-urban agriculture

1.1. A challenging future of peri-urban agriculture

Peri-urban agriculture is agricultural land use around a city. At the early stage of city growth, peri-urban agriculture had the main role of food production. It had a static pattern mainly determined by distance to city center, in accordance with the Isolated State model proposed by Von Thünen in 1826 (Johnson, 1962; Sinclair, 1967). The world urban population grew more than fivefold between 1950 and 2014, resulting in rapid growing of big cities (United Nations, 2014). Substantial agricultural lands have been lost for urban expansion or abandoned as land reserve for construction (Nelson, 1990).

Peri-urban agriculture is since long in the center of the "Rural-Urban Fringe" where dramatic land use changes and conflicts exist (Pryor, 1968; Heimlich and Barnard, 1992; Darly and Torre, 2013; Gong et al., 2014). Agricultural lands are also strongly consumed for the expansion of natural and recreational spaces (Berry, 1978; Bryant, 1984; Curran-Cournane et al., 2014). It is progressively recognized that peri-urban agriculture provides multiple benefits beyond food production (Nelson, 1990). There is a rise of urban-to-rural migration in North America and Europe in search of being close to rural open space and lifestyle. But the migration paradoxically stimulated a low density and scattered urban sprawl, and continuously pushed the rural landscape outward (Davis et al., 1994; Caruso, 2001; Paquette and Domon, 2001; European Environment Agency, 2006; Schneider and Woodcock, 2008).

1.2. Existing strategies for preserving peri-urban agricultural lands

Extensive researches tried to propose strategies that prevent conversion of farmlands to urban use.

The first category of strategies is the restrictive zoning. For example, the United Kingdom issued London Green Belt Act in 1935 and established Green Belts around several major cities and conurbations in 1950s (Gant et al., 2011). According to the review of Alterman (1997) and Bengston et al. (2004), other forms of zoning existed besides the Green Belt policy, such as the Urban Growth Boundary and Exclusive Agricultural Zones. The Green Belt is a green girdle encircling the city established as a barrier against urban expansion towards the open countryside. The Urban Growth Boundary is a physical line to separate an urban area from surrounding rural areas. It is periodically reassessed and expanded as needed. Exclusive Agricultural Zones are legally recognized areas designated to keep agricultural land use. Agricultural districts are similar instruments but the enrollment of farmers is voluntary. The Regional Natural Parks in France are such zones established based upon agreement among multiple stakeholders within the areas (Bryant, 1986).

The second category is subsidizations to farmers, such as tax programs that reduce the property tax burden of farmers close to urban development (Nelson, 1990). Purchase or transfer of development rights are also programs of subsidization, which are popular especially in United States (Daniels, 1991; Rielly, 2000; Bengston et al., 2004). A landowner's property rights are explained as a bundle of separate rights, and the farmer voluntarily sells his development rights to the government or a public funding. So he receives compensation for keeping agricultural use on the land.

These policies were found not effective. The zoning policies without compensation to farmers were not capable to limit the leapfrog or continual shifting of urban growth boundary, especially in developing countries because of illegal settlements (Aguilar, 2008) or lack of a legal basis for the implementation of agricultural zoning (Sharifi et al., 2014). Tax programs were effective in retaining farmland in the near term, but stimulated speculation and urban sprawl in the long term (Nelson, 1990). Random purchases of development rights could not prevent scattered subdivision of farmland tracts, resulting in fragmented lands unsuitable for agricultural production (Nelson, 1990). Most importantly, these instruments were more effective in protecting open spaces or rural characteristics than in ensuring a thriving agricultural sector, as revealed by the massive conversions from productive agricultural lands to hobby farms, golf courses, equestrian centers, allotments and others (Daniels, 1991; Bryant, 1986; Alterman, 1997; Gant et al., 2011; Paül and McKenzie, 2013). Koomen et al. (2008) even claimed that conversion from agricultural lands to natural spaces was an effective solution to preserve open space in the Netherlands.

Ultimately, multiple benefits of agricultural lands, like environmental, recreational and social value, were not integrated with the food or material production. There was no expression for the value of these multiple benefits. Compensations to farmers were only calculated based upon the commercial value of food or material production, which were hardly competitive in the land market. Emphasis on environmental value also drove the conversions to non-agricultural use. Meanwhile, these instruments lack a perspective at higher level, e.g. landscape scale, which is necessary for the integration of multiple benefits with agricultural production.

1.3. Relations with “Urban Agriculture”

Peri-urban agriculture is an integrated part of “Urban Agriculture”, which defines the agricultural activities located within and surrounding urban area and serving for urban population (Smit and Nasr, 1992; Maxwell, 1995; Smit et al., 1996; Mougeot, 2000; Drechsel and Dongus, 2010). The growing urban needs for multiple agricultural goods and services create opportunities that integrate agricultural activities in urban policies concerning food security, poverty reduction, waste recycling, and land use planning (Smit et al., 1996; van Veenhuizen, 2006; FAO, 2007; De Zeeuw et al., 2011; Aubry et al., 2012).

However, the vision of “Urban Agriculture” is dominated by the angle of urban demands. Peri-urban agriculture is never simply a subordinated part for providing services to the city. Urban waste or wastewater use may arouse opposition from peri-urban stakeholders for the risk of contamination depending on the particular socio-ecological context on site (Drechsel and Kunze, 2001; Cofie, 2006; Weinberger and Lumpkin, 2007). The widespread low maintaining hobby farming in favor of city dwellers may threaten productive peri-urban agriculture by raising land prices, fragmenting land holdings, or accelerating abandonment (Daniels, 1986). Peri-urban agriculture is not all in the domain of “Urban Agriculture”. Research on peri-urban agriculture should consider the relations among different stakeholders regarding the management of multiple agricultural benefits.

2. Ecosystem Services and agriculture

2.1. Definition of Ecosystem Services

Ecosystem Services (ES) are benefits that human populations derive directly or indirectly from ecosystem functions, as defined by Costanza et al. (1997). ES research claims that human-caused environmental degradation largely results from ignorance of ES value or lacking of instruments to consider that value in the decision-making systems. The United Nation’s Millennium Ecosystem

Assessment program (MEA, 2003, 2005) distinguished four categories of ES: provisioning services, regulating services, cultural services, and supporting services.

Ecosystem-service cascades explains the "production chain" of ES, which include the following stages: ecosystem structure and process, function (ecosystem capability to provide services), service, benefit, and value (Haines-Young and Potschin, 2010, de Groot et al., 2010). The mechanism of Payments for Ecosystem Services/Environmental Services (PES) has been designed to solve public goods problem, based upon identification of the providers and beneficiaries of ES (Pagiola et al., 2005; Wunder et al., 2008). The strategy of ES has gained a big success in improving natural ecosystems management during the past twenty years. It becomes also interesting for agricultural research because agricultural activities basically rely on the functioning of agro-ecosystems.

2.2. Agro-ecosystem

The concept of agro-ecosystem appeared as an adaptation of "ecosystem" thinking in agricultural research. It promoted consideration of the ecological context beyond the narrow view that considered agriculture merely as a linear, controllable, economic activity (Loucks, 1977; Conway, 1985; Altieri, 1999; Gliessman, 2004; Cabell and Oelofse, 2012). Comparing to natural ecosystem, the primary particularity of agro-ecosystem is its highly simplified structure and the non-self-sustaining energy flow and matter cycling. Constant human interventions are required to kill the pest, guarantee water supplying, and maintain nutrient and carbon level in the soil.

Agro-ecosystem is a social-ecological system, including necessary human inputs such as pesticides, irrigation water, fertilizers and labors, and also related social, economic, and market elements. The objective of the early work on agro-ecosystem was to ameliorate the ecological processes linked to food production, regarding four system properties: productivity, stability, sustainability and equitability (Conway, 1985). With the rise of ES concept, research on agro-ecosystem gradually recognized multiple ES and impacts beyond the production of food and materials (e.g. regulation of climate and water, detoxification) from agriculture, as well as intermediate ES that are necessary for the functioning of agro-ecosystem itself, such as the biodiversity, fertility of sol and recycling of nutrient (Altieri, 1999; Gliessman, 2004; McKey et al., 2010; Cabell and Oelofse, 2012). These studies found that traditional agro-ecosystems such as polycultures and agroforestry systems and alternative ones like organic farming could be capable of self-regulation.

2.3. Ecosystem Services and agriculture

The estimation of Costanza et al., (1997) on the global value of ES from cropland included only pollination, biological control and production service, and considered that the value of cropland was negligible in providing recreational service or habitat/refugia. Agricultural expansion was principally blamed for global ecosystem services damage (MEA, 2005). Subsequently, growing research largely enriched the framework of ES from and to agricultural ecosystems (Swinton et al., 2007; Zhang et al., 2007; Power, 2010; Ma and Swinton, 2011).

A range of regulating and supporting ES were considered as necessary inputs to agro-ecosystem, including soil structure and fertility, nutrient cycling, water provision, biodiversity, pollination, biological control of pests, water regulation, atmospheric regulation, and others. Besides production of food and materials, agriculture was also considered supplier of wildlife habitat, climate change mitigation, recreation, esthetic service and other ES. Furthermore, the framework also revealed "ecosystem disservices" to agriculture (e.g. pest damage, competition for water and pollination) and from agriculture (e.g. habitat loss, nutrient runoff, pesticide drift).

The aim of ES research on agriculture is to promote the change of agricultural practices for alleviation of the agricultural image as polluter and consideration of public goods and services. Effective instruments can be hopefully created for preservation of agricultural lands. For example, the mechanism of PES is interesting for ameliorating the performances of Agri-Environment Measures (AEM), major policy tools in Europe to improve environmental performance of agriculture (Rega and Spaziante, 2013, Wynne-Jones, 2013). AEM were designed in the 1980s to compensate farmers for their loss of income associated with environmental protection measures (European Commission, 2005). There are increasing doubts on the efficiency in monitoring and evaluation of AEM policies (Kleijn and Sutherland, 2003; Schroeder et al., 2013). Peri-urban agriculture has close contacts with the urban population who is highly demanding of these services. PES mechanism also offers marketable incentives that integrate multiple alternative benefits with the production of food and materials from peri-urban agriculture.

2.4. Challenges of Ecosystem Services in agricultural research

Agro-ecosystems are more complicated than natural systems for being highly modified, socio-ecological systems. It is difficult to distinguish the contributions of ecosystems from the contributions of farmers. It is also confusing to define the human-caused pesticide drift and nitrogen leaching as embedded “disservices” of agro-ecosystem (e.g. Swinton et al., 2007; Zhang et al., 2007; Power, 2010). An ecosystem can include humans and their artifacts (Pickett, 2002), but if human effects are always confused with natural effects, it is difficult to halter the growing dependence of modern farming on human inputs. For this reason, Lugo (2008) and Aznar et al. (2009) proposed to distinguish the contributions of farmers (environmental service) from contributions of ecosystem (ecosystem service). Their focus then turned from ecosystem services to environmental services.

Meanwhile, environmental concerns are hard to be integrated to farming systems for being considered as constraints by the farmers, such as reduction of pesticides and mineral fertilizer use. Policies targeting the protection of a certain ES may harm the livelihood of farmers and other actors (Bonnal et al., 2012; Maris, 2014). The concept of ES which till now is nature-driven needs to be mediated into the social and economic dimensions. Scientific attempts are emerging to conciliate ecology with action (Gunnell, 2009) or to improve the combination of ecological, social, economic and political dimensions in ES research (Arnauld de Sartre et al., 2014).

Attention should also be paid to avoid the abuse of the concept. The equation of ES with influence, land function or consequence, weakens the effectiveness of the concept. For example, an “ES” of peri-urban agriculture to limit urban expansion is hard to understand. It is rather a human choice than a benefit from the functioning of agro-ecosystem. Abuse leads to abandonment of a concept, as shown by the example of Multifunctional Agriculture (MFA), a similar concept on multiple benefits from agriculture and being criticized as lacking precision (Garzon, 2005). Thus, in order to compensate the limitations of ES as noted above, it’s better to integrate ES with other concepts than to unreasonably enlarge the scope of ES.

3. Multifunctional Agriculture

3.1. Definition of Multifunctional Agriculture

Multifunctional Agriculture (MFA) analyzes the jointly produced economic, social and environmental functions from agricultural activities beyond the production of food and fiber. It was highly promoted by the Organisation for Economic Cooperation and Development and the European Union in 1990s in both research and policy making (European Community, 1998; OECD, 2001).

Existing MFA projects on peri-urban agriculture focused more on socio-economic dimension than environment protection (Vandermeulen and Van Huylenbroeck, 2008). Prioritized functions were food supply, landscape amenity and environmental role against flood risk (Zasada, 2011; Aubry et al., 2012).

3.2. Role of MFA in the policies of France and Europe

In France and Europe, research and policies of MFA gradually reached its height from early 1990s on the occasion of the reforms of Common Agricultural Policy (CAP) (Pisani, 1994; Groupe de Bruges, 1996; Laurent and Mouriaux, 1999; Laurent, 2002; Hervieu, 2002; Aumand et al., 2006). The reform of CAP reduced direct price supports and shifted to area-based income supports to farmers with the aim to sustain necessary land occupancy pattern for joint production of environmental goods at a landscape scale (Potter and Burney, 2002; Bills and Gross, 2005; Gomez y Paloma et al., 2013). MFA research made very important contributions by revealing the mechanism of jointness in production processes (Wossink et al., 2001; Schmid and Sinabell, 2004). At the Berlin Summit on the Agenda 2000, the European Union created the second pillar of the CAP around rural development and MFA (Hervieu, 2002).

In France, the concept of MFA was officially confirmed by the Agricultural Orientation law (LOA) in 1999; the instrument of Farming Territorial Contract (CTE) was established, which was a contract between farmers and the state about the delegation and payments for public services destined to stakeholders at the territorial level (Bonnal et al., 2012). The concept of MFA then failed in the political world for being criticized as “agricultural protectionism” (Bonnal et al., 2012) or lacking of precision. The instrument of CTE was also replaced by the Contract of Sustainable Agriculture (CAD) in 2002 and later by instruments associated with Agri-Environmental Measures. PAC reform now is turning to market incentives (e.g. PES) for the post-2013 period (Gomez y Paloma et al., 2013).

3.3. Future of MFA

The failure in political world does not mean that the concept of MFA is valueless. Focusing on the performance of agriculture, MFA strategy can more directly guide the overall management of farmers’ activities. It is rather the improper design of policy instruments that have caused market distortion. MFA is not incompatible with more efficient commercial incentives (van Huylenbroeck et al., 2007) or a remuneration/penalization policy frame directly linked to public goods/negative impacts (Blandford and Boisvert, 2002).

The flexibility covering a wide range of contributions from agriculture is an advantage of the concept which stimulates linkages with the territory, among multiple scales and between different disciplines, and makes MFA a promising way towards sustainable development (Caron et al., 2008). Scholars complained that it was very difficult for MFA to completely decouple environmental objectives with agricultural production (Potter and Burney, 2002). Nevertheless, this is beneficial for the preservation of peri-urban agriculture, which avoids the conversion of agricultural lands to extensive use like hobby farm or natural lands.

Certainly, MFA needs to overcome the shortcomings. First, the concept needs a firm base to specify the definition of agricultural functions. Different countries have diverse perspectives on multifunctional agriculture (Moon, 2012). The definition should allow communication among different perspectives without becoming too vague. Second, MFA lacks consideration on the role of ecosystem services, i.e. benefits from the functioning of agro-ecosystem. It always takes agricultural system as a human-made production system that pursues additionally positive environmental effects and reduction of negative influences.

4. Integrated approaches of ES and MFA

ES and MFA have similar objectives to recognize multiple agricultural benefits and impacts beyond the production of food and fibre. Each has advantages and also shortcomings. According to the above discussions, the two concepts are highly complementary. It is a good strategy to integrate two complementary mature concepts when there is too much uncertainty to create a new one. The criticisms are useful in indicating the shortcomings of a concept, but it's not reasonable to move towards a quick abandonment of the concept:

For example, Maris (2014) claimed that PES was problematic because it resulted in a utilitarian view of nature by "selling nature". But in fact, PES is just an instrument to promote the maintenance of ES, and does not equal the true value of ecosystem services. In the logic of environmental regulation, costs are paid by farmers; while in the logic of PES, costs are paid by the society (Desjeux et al., 2011). It does not mean that nature is sold by one person to another. Another tendency is turning from ecosystem service to environmental service as discussed above. The concerns of environmental services focus on the contributions or sacrifices of farmers to the providing of environmental benefits. Studies on "environmental services" are useful for the creation of effective instruments to motivate the farmers (Wunder et al., 2008; Aznar et al., 2009). However, the contributions of the ecosystem should not be ignored, for example, the contributions of various regulating service and supporting service to the production of final services (e.g. food and materials, esthetic and cultural service).

An integrated approach of ES and MFA can promote integration of the alternative agricultural benefits with the production of food and materials, avoiding over emphasis on productivity or environmental concerns. Peri-urban agricultural lands can be really preserved in that case. ES can be a firm base for the definition of agricultural functions, thus to improve the precision of MFA. Based upon ES cascade, the integrated approach can properly consider the role of ES, and manage a self-regulating agricultural system. MFA combines economic, social and environmental dimensions so can be a perfect mediation to integrate the logic of ES with the logic of economic and social benefits. The integrated approach will also help to distinguish the contribution of ecosystem and human actions. Especially, it will provide overall strategies for farmers to manage their activities and a framework about the relationships among multiple stakeholders. Integrated approach of ES and MFA is innovative; research is very rare in this domain.

5. Objectives of the dissertation

The objective of the dissertation is to explore an integrated approach of ES and MFA for the preservation of peri-urban agricultural lands. The first part is dedicated to the development of an integrated framework of ES and MFA for the research of peri-urban agricultural lands. The second and third parts are in-depth studies on management of abandoned farmlands and agricultural recycling of urban wastes in Ile-de-France Region, respectively. The aim of the in-depth studies is to demonstrate how the integrated approach of MFA and ES works on concrete problems linked to peri-urban agriculture. Multi-scale analyzes were carried out for the two in-depth studies.

5.1. Development of an integrated framework of ES and MFA for peri-urban agriculture

5.1.1. Comparative review of MFA and ES in agricultural research

Two scientific communities independently focus on MFA or ES. They have broad interest in sustainable agriculture but limited interaction and exchange. There are mainly two views in the literature about the relations between MFA and ES. The first perceives a trend of increasing use of ES and declining use of MFA (e.g. Bonnal et al., 2012). The other views the two concepts as the same things "under different headings" (e.g. Renting et al., 2009). So the primary work is dedicated to a comparative review on ES and MFA in published agricultural research.

The review addresses the following two specific objectives: first, it compares the publication trends, ideologies and research approaches of MFA and ES; second, it proposes dialogs and an integrated research framework that combine MFA and ES. The general framework mainly concludes a MFA strategy for farmer to consider multiple ecosystem services and disservices to and from agriculture as inputs and outputs of his farm.

5.1.2. Further development of the integrated framework for peri-urban agriculture

Application to a specific context as peri-urban agriculture requires further work to combine the demand side. The output ES from agro-ecosystem are consumed differently in different social economic structure, so the multifunctionality of a farm varies. For example, food supply varies with the commercial system. When products from peri-urban agriculture are largely destined to international markets, the increasing provisioning ES do not necessarily improve food function to the nearby urban dwellers.

Peri-urban farmers have direct contacts with a variety of stakeholders. Food security has critic meaning for the growing population in the city, especially when urban needs are rising for local food (Aubry and Kebir, 2013). Comparing to strong urban demands, peri-urban agriculture is underproducing environmental values and landscape elements (Zasada, 2011). Conventional farmers are marginally motivated to modify practices that maintain soil fertility, preserve biodiversity, or reduce pesticides use (Van Huylenbroeck et al., 2005; Torquati et al., 2008). Direct payments for these ES usually are far less attractive than the income from food production or the subsidies from land expropriation (Caro-Borrero et al., 2015).

Therefore, the integrated framework needs to combine ecological, social and economic dimensions to link ES with agricultural functions, in order to propose overall strategies for farmers' activities. It also needs to understand the interactions among multiple ES/functions from peri-urban agriculture. This is the key for the permanent problem of coordinating urban needs for food, land and environmental services, to avoid the paradox that rise of urban-to-rural migration in search of rural open space and lifestyle drove rapid consumption of peri-urban agricultural lands. The integrated framework of ES and MFA is thus been further developed.

5.1.3. Application in the case of Ile-de-France Region

The integrated framework is then applied in the case of Ile-de-France Region, with the hope to enlighten policy making for peri-urban agricultural preservation.

Ile-de-France Region (Paris Region) is one of the world's major metropolitan regions. It was profoundly affected by urban expansion and peri-urbanization in the past century (Boyer, 1988; Poulot and Rouyres, 2007), but remains to have 50% of its surface occupied by agricultural activities. ES degradation caused by agricultural industrialization contracts with the increasing urban demands for local food, recreation, climate regulation and other services (Poulot and Rouyres, 2007; Poulot, 2008; Aubry and Kebir, 2013). Evolution of policy instruments, especially the master plans, revealed the planners' intention of considering different services/functions of agriculture (Bryant, 1986; Charvet, 2003; Poulot, 2011). The case of Ile-de-France is meaningful for drawing suggestions to other metropolitan regions.

Before the further development of the integrated framework, investigations are provided on the land loss, structural evolution and regional pattern of agricultural land uses in Ile-de-France. Then, the application of the general framework in the region looks into changes of ES and MFA following the evolution of agricultural lands, and how social needs or consumption of ES and MFA have driven the evolution of different agricultural land uses, such as open-field cereal crops, vegetable cultivations, fruit trees and natural prairies.

5.2. In-depth studies on abandoned farmlands and agricultural recycling of urban wastes

Two in-depth studies are carried out in Ile-de-France Region to demonstrate how the integrated approach of MFA and ES works on concrete problems linked to peri-urban agriculture. It concerns the combination of ecological, social and economic dimensions, interactions among multiple stakeholders and other questions. Management of abandoned farmlands and agricultural recycling of urban wastes are selected for particular reasons.

5.2.1. Management of abandoned lands in peri-urban agriculture

The comparative trends of land abandonment and reuse of abandoned lands signify the destiny of peri-urban agriculture in the big metropolitan areas. It is well known that agricultural lands are suffering great loss to urban expansion. The situation is even worse when abandoned farmlands are quite commonly seen in the big metropolitan region like Ile-de-France.

Abandoned farmlands in a restrictive sense are lands no longer used by agriculture or any other rural economic activity (Baudry, 1991). They become "abandoned lands" not necessarily because there is no property owner, but because the total termination of management has left the lands to their own spontaneous succession. A vegetation cover is then rapidly restored and evolves from grasses to brushes and then to forests in around 30 years when the local climatology and ecology conditions permit (Baudry and Acx, 1993). Being "vacant" lands in terms of land use, abandoned farmlands are never left behind by land use planners or other stakeholders, especially in peri-urban area. They are to be converted to constructive lands, urban green parks, ecological corridors, or certain forms of urban agriculture. Research on this process can help peri-urban agriculture to adapt to the urban demands of ES and agricultural functions, instead of crying desperately as a victim of urbanization.

5.2.2. Agricultural recycling of urban organic wastes

Agricultural recycling of urban organic wastes is particular because it is based upon two ES, namely, the ES of waste breakdown and ES of fertilization according to the general framework developed in part 1. So the waste producers can be both suppliers of fertilizer and requesters of waste breaking-down service, and correspondingly, the farmers are both requesters of organic fertilizer and suppliers of waste breaking-down service. In an ideal situation, the waste producers and farmers have a simple "win-win" relationship. That's the case when urban organic wastes were highly appreciated by farmers in the old historic period in France (Phlipponneau, 1956; Moriceau, 1994; Barles, 2005).

However, urban wastes are not naturally harmless. Numerous studies revealed the risks linked to accumulation of heavy metals, pathogens and other micropollutants in soil and food (Déportes et al., 1995; Raven and Loeppert, 1997; Smith, 2009). Long term use of untreated waste water of Paris city from the end of 19th century followed by sewage sludge spreading of SIAAP caused severe soil pollution of heavy metals in the spreading zone near Achères (Mandinaud, 2005). The incident built a strong negative social image for land application of urban wastes in France.

Regulations were made in Europe and North America to strictly limit the concentration level of micropollutants (McGrath et al., 1994; Harrison et al., 1999; Dhaouadi, 2014). Many studies proved with experiments that agricultural use of urban organic wastes in accordance with the French regulations had no significant impact on soil and plants (Delmas et al., 2000; Baize, 2009; Houot et al., 2009; Brochier et al., 2012). But the reality is far more complicated than a simple win-win relationship between waste producers and peri-urban farmers. The technic control on risk problems by regulations, alone, does not resolve all problems.

Weights on the balance of agricultural use of urban wastes shifted since 20th century from the side of fertilizer to the side of urban waste eliminating in France (Nicourt and Girault, 2003; Joncoux, 2013). The European directive (91/271/EEC) strengthened requirements on wastewater collecting and treatment. Agricultural recycling is still the predominant choice of sewage sludge disposal (Kelessidis and Stasinakis, 2012) and also a promising solution for building integrated ecological waste management systems (Magid et al., 2006). But it may be embarrassing to move towards "payments for ecosystem services" to farmers for eliminating of urban wastes. Agricultural lands are not waste bin of the city. The fertilization effects (Ayuso et al., 1996; García-Gil et al., 2000; Ros et al., 2006; Ghaly and Alkoaik, 2010) are always the basic motivation for farmers to take urban organic wastes. Study on urban waste recycling may thus shed light on the proper use of ES instruments for peri-urban agriculture.

5.2.3. Proceeding with a land use type v.s. a service/function

The two themes are both selected to explore the methodology of integrated approach of MFA and ES, with the hope to illuminate future research. The study on conversions of abandoned farmlands proceeds with the management of a particular land use type; while the study on agricultural recycling of urban wastes proceeds with the management of a ES/agricultural function.

Land use types or characteristics were commonly linked to ES assessment and management in the literature (Costanza et al., 1997; Troy and Wilson, 2006; Ma et Swinton., 2011), as well as the reformed CAP and Agri-Environmental Measures (Potter and Burney, 2002; Donald and Evans, 2006). Burkhard et al. (2009, 2014) even concluded a matrix of the different land cover types' capacities to provide selected ecosystem goods and services. Study on the appearance and management of abandoned farmlands reveals the mutual relations between land use change and evolution of ES/land functions. Study on agricultural recycling of urban wastes investigates the multiple influences on the supply-demand relationships. These approaches may be used for other land use types and ES/agricultural function, respectively.

5.3. Multi-level analyzes for the two in-depth studies

Multi-level analyzes are carried out for the two in-depth studies, including both an analysis on the regional pattern and a local investigation on practices and perceptions of different actors at two local areas. The two local areas investigated for abandoned farmlands are the bench of Seine at Triel-sur-Seine and Carrière-sous-Poissy. Another two local areas for investigation on agricultural recycling of urban wastes are the Plaine-de-Versailles and the Plateau-de-Saclay.

5.3.1. Multi-level issue in the management of abandoned farmlands

Management of abandoned farmlands is not a one-fold issue; a multi-scale approach is necessary. First, land abandonment is occurring within a landscape and reflects the change of landscape structure (Baudry, 1991). Ecological effects can only be told at the regional level. Analysis on abandoned farmlands within the context of regional land use pattern provides a comprehensive perspective to understand, predict and manage abandonment at regional scale. There are extensive studies on remote rural areas (Gellrich and Zimmermann, 2007; Díaz et al., 2011; Navarro and Pereira, 2012), but few about peri-urban areas. One example: La Greca et al. (2011) proposed a land use suitability model based on land cover analysis and fragmentation analysis to guide the regional management of land use, including the reuse of abandoned farmlands, in Catania metropolitan area of Italy.

Then, management of abandoned farmlands is inevitably a local issue, concerning a great heterogeneity that can be hardly perceived at the regional level. An abandoned land of 1000 m^2 is striking in the neighborhood and in the municipal land use management, but is almost impossible to notice at the level of a big metropolitan region like Ile-de-France.

Furthermore, interactions between different scales are not negligible. Massive abandonment happens in the area where a national project is implanted. It is necessary to understand the mismatches and conflicts between local actors and managers at higher level. The study of Gervais and Jaouich (1984) on two lots of abandoned farmlands in the suburb of Québec revealed that the return of abandoned farmlands to agriculture may be difficult in local cases in despite of the favorable regional policy for peri-urban agriculture.

5.3.2. Multi-level issue in the agricultural recycling of urban waste

For agricultural recycling of urban wastes, one of the biggest problems is the mismatch between regulations at superior level and local reality. First, different countries adopt widely different numerical limits regarding the level of micropollutants in urban organic waste or soil, “creating unease among the regulatory authorities worldwide” (McGrath et al., 1994; Kelessidis and Stasinakis, 2012). Second, local heterogeneity results in difficulties in inter-scale management. The European and French regulations are extremely strict and complicated for land application of sewage sludge, but contrary to what policy-makers might expect, the society has become progressively cautious and reluctant to agricultural use of sewage sludge, especially in peri-urban area. Third, different actors have different concerns regarding agricultural use of urban wastes, such as the home gardener, farmer, waste producer, neighbor, environmentalist and agronomist (Harrison et al., 1999).

The fast growing urban wastes are more and more collected by inter-municipal cooperation and peri-urban farmers’ willingness in accepting urban wastes is influenced by multiple factors other than the fertilization effect. The flows of urban wastes to agricultural lands are in fact influenced by a variety of stakeholders at different scales.

6. Structure of the dissertation

The dissertation is organized into three main parts after this general introduction (Fig. 0-1). Part 1 develops an integrated framework of MFA and ES for the research of peri-urban agriculture. It includes three chapters. Chapter 1 provides a comparative review on MFA and ES within the context of agricultural research and proposes an integrated framework concluding a MFA strategy for farmer to consider multiple ES and disservices to and from agriculture as inputs and outputs of his farm. Chapter 2 presents the analysis on agricultural land loss, structural evolution and regional pattern of agricultural land uses in Ile-de-France. Chapter 3 further develops the integrated framework of MFA and ES by combing the demand side in the specific context of peri-urban agriculture, and applies the general framework in the case of Ile-de-France. The application in the region investigates the changes of ES and MFA following the evolution of agricultural lands, and how social needs of ES and agricultural functions have driven the evolution of different agricultural land uses.

Part 1 (Chapter 1~3): Development of an integrated framework of MFA and ES

Chapter 1: Comparative review on MFA and ES in agricultural research and an integrated framework of MFA and ES

Chapter 2: Evolution of agricultural land use in the Ile-de-France Region

Chapter 3: Further development of the integrated framework of MFA and ES in the peri-urban context and application in Ile-de-France Region

Multi-level in-depth studies to show how the integrate MFA and ES approach works on concrete problems linked to peri-urban agriculture.

	Part 2 (Chapter 4 ~ 5): Management of abandoned farmlands in Ile-de-France Region	**Part 3 (Chapter 6 ~ 7): Agriculture recycling of urban waste in Ile-de-France Region**
Objective	Mutual relations between land use change and evolution of ES/land functions	Multi-scale influences on the supply-demand relationships
Analyzes		
Regional pattern analysis	▪ Regional land use change trajectories. ▪ Distribution of land abandonment. ▪ Different situations of land abandonment. ▪ Comparative trends of land abandonment and reuse of abandoned lands.	▪ Regional pattern of sewage sludge production. ▪ Distribution of suitable agricultural lands for sewage sludge application. ▪ Flows of sewage sludge in Seine-et-Marne. ▪ Estimation of the region pattern of crop succession types.
Local analysis	▪ Interviews with different actors in 3 municipalities in a bench of Seine and the PNR of Chevreuse about their practices and perceptions of abandoned lands ▪ Categories of actors	▪ Interviews with different actors in the Plaine de Versailles and the Plateau de Saclay about their practices and perceptions of the sector. ▪ Multi-scale influences. ▪ Categories of farmers.

General discussions and conclusions

▪ Perspective of the integrated approaches of MFA and ES for the preservation of peri-urban agricultural lands?
▪ Value of the multi-level analyzes?
▪ General implications to land use management in big metropolitan regions?

Fig. 0- 1. Structure of the dissertation. MFA: Multifunctional Agriculture, ES: Ecosystem Service

Part 2 and Part 3 are the two multi-level in-depth studies in Ile-de-France Region to show how the integrate MFA and ES approach works on concrete problems linked to peri-urban agriculture. Part 2 works on the management of abandoned farmlands and Part 3 on agricultural recycling of urban wastes (sewage sludge and green waste compost). The two parts have similar structures, both including an analysis of regional pattern and a local analysis on the practices and perceptions of different stakeholders. Each part has two chapters, the first chapter describing materials and methods, and the second presenting the results.

The dissertation ends with the general discussions and conclusions. This section discusses the perspective of integrated approaches of MFA and ES on the preservation of peri-urban agricultural lands, the value of multi-level analyzes, and general implications to land use management in big metropolitan regions.

Part 1

Development of an integrated framework of MFA and ES for peri-urban agriculture

This part includes three chapters. Chapter 1 provides a comparative review on MFA and ES within the context of agricultural research and proposes an integrated framework concluding a MFA strategy for the farmer to consider multiple ES and disservices to and from agriculture as inputs and outputs of his farm. Chapter 2 presents the analysis on agricultural land loss, structural evolution and regional pattern of agricultural land uses in Ile-de-France Region. Chapter 3 further develops the integrated framework of MFA and ES by combing the demand side in the specific context of peri-urban agriculture, and applies the general framework in the case of Ile-de-France. The application in the region investigates the changes of ES and MFA following the evolution of agricultural lands, and how social needs of ES and agricultural functions have driven the evolution of different agricultural land uses.

Chapter 1

Comparative Review of Multifunctionality and Ecosystem Services in Sustainable Agriculture*

1. Introduction

Concerns regarding productivity-driven agricultural management intensified from the early 1970s due to its dramatic effects on environmental quality and rural vitality (Holdren and Ehrlich, 1974; Knickel, 1990). Researchers turned to traditional farming systems or new rural activities, such as farm-based tourism to explore sustainable strategies (Gliessman et al., 1981; Evans and Ilbery, 1989; Altieri, 1992; Meeus, 1993). Multifunctional agriculture (MFA) and ecosystem services (ES) emerged from these pursuits, and have been considered, after being promoted by international programs, to be two important concepts for sustainable agricultural research and policy-making.

Agriculture is considered multifunctional when it has other additional functions to food and fibre production. The concept gained importance after being addressed in the Agenda 21 documents of the Rio Earth Summit (UNCED, 1992) with respect to sustainable development. It also was promoted by the European Union (EU) to justify agricultural supports in World Trade Organization (WTO) negotiations. The EU interpretation was normative, focusing on multiple roles assigned to agriculture by society (European Community, 1998). The Organisation for Economic Cooperation and Development (OECD) developed an analytical framework for MFA based primarily on a positive interpretation, considering agriculture as an economic activity that has multiple, interconnected outputs (OECD, 1998, 2001). This vision of MFA, combined with political demands for scientific output, stimulated many research programs (Laurent, 2002).

The concept of ecosystem services was introduced in 1981 (Ehrlich and Ehrlich, 1981) as a joint initiative of economists and ecologists. They emphasized that valuing nature's services in decision systems would correct misperceptions regarding the relationship between humans and nature. Costanza et al. (1997) defined ES as "the benefits human populations derive directly or indirectly from ecosystem functions," and calculated the global value of ecosystem services from different ecosystems. This work is considered a milestone that mainstreamed the research. The United Nation's Millennium Ecosystem Assessment (MEA) program (MEA, 2003, 2005) greatly stimulated ES research and international projects, and firmly placed this concept in the policy agenda (Gómez-Baggethun et al., 2010).

MFA and ES were conceived during the same period, and had similar objectives to recognize agricultural benefits and impacts beyond the production of food and fibre. However, MFA and ES have progressed in different directions from similar origins. MFA horizontally enriched agricultural functions to include food security, environmental protection, and rural vitality, and MFA research investigates how these functions are jointly produced. ES vertically further developed the concept

* Published work, see Huang et al., 2015. Comparative review of multifunctionality and ecosystem services in sustainable agriculture. Journal of environmental management 149: 138-147.

from “ecosystem functions” to “ecosystem services”, and pioneered strategies incorporating economic valuation and incentives (Haines-Young and Potschin, 2010). ES initially oriented toward natural ecosystems and blamed agricultural expansion for global ecosystem services damage (MEA, 2005). Subsequently, ES recognised agriculture as a provider and consumer of multiple ecosystem services (Swinton et al., 2007; Zhang et al., 2007).

Agriculture is a complicated socio-ecological system, posing many challenges to both MFA and ES communities. MFA must develop greater precision for the development of more effective policies (Garzon, 2005), whereas ES trends toward monetization and commodification should be carefully considered to avoid controversial outcomes (Gómez-Baggethun et al., 2010). Cooperation between the communities would be beneficial, particularly on common issues involving multidisciplinary approaches (Cowling et al., 2008; Renting et al., 2009). Effective communication between the communities is rare; some publications mention alternative concepts but rarely explore alternative approaches (e.g. MEA, 2005; Randall, 2007; Jordan and Warner, 2010).

The goal of this work is to provide a common platform for pooling and exchange of ideas and methodologies that could serve as a springboard to new levels of cooperation. We provide a comparative review of MFA and ES within the context of agricultural research. We address the following two specific objectives: first, we compare the ideologies and research approaches of MFA and ES; second, we propose dialogs and an integrated research framework that combine MFA and ES. Section 2 presents MFA and ES trends based on publication statistics (Section 2.1), compares the ideological bases of MFA and ES (Section 2.2), and compares MFA and ES research approaches for classification, valuation, trade-off, planning, and management (Section 2.3). Section 3 discusses possibilities for communication between MFA and ES communities by considering two specific questions, and proposes an integrated conceptual framework.

2. Literature review of multifunctional agriculture and ecosystem services

2.1. Publication statistics

Publication statistics were calculated to examine MFA and ES research trends. First, we identified all articles using MFA and ES that were indexed by Web of Science and published from 1975 to November 15, 2013. The search strategy for MFA included publications using the ideology of MFA in research on forestry (e.g., Brunet, 2007), prairie (e.g., Wiltshire et al., 2011), green infrastructure (e.g., Lovell and Taylor, 2013), land use (e.g., Wiggering et al., 2006), and landscapes (e.g., Jordan et al., 2011). The search strategy for ES included alternative names such as ecological services and environmental services (Lugo, 2008). Then, we identified publications involving agricultural problems, publications addressing multiple ecosystem services, and publications using both MFA and ES. Thus, we classified the publications into the following eight categories: MFA; ES; multiple ES; MFA and ES; and the subsets of the four preceding groups that specifically involved agriculture. Detailed explanations of the methods and figures are given in the online Appendix.

The results suggest that MFA and ES publications have similar global trends. They emerged in the 1980s, quietly incubated in the 1990s, and flourished in 2000s. MFA publications steadily increased from 2001, whereas ES publications increased explosively right after the end of the MEA program in 2005. The subsets of MFA and ES approaches that specifically address agricultural problems have less contrast regarding quantity than the total publications of MFA and ES. Publications on multiple ES appeared in 1992, and publication using both MFA and ES appeared in

1999. For publications addressing multiple functions or services involving agriculture, MFA publications started increasing earlier and grew faster than those of ES, but the latter show much stronger growth in recent years. Publications using both MFA and ES are a small proportion of the total (1.6% of ES publications and 13.8% of MFA publications). These results do not support the conclusions of Bonnal et al. (2012), who perceived trends of increasing ES use and declining MFA use. This is because ES engages in a broad range of subjects other than agriculture, and research can focus on a single ES. Without categorizing or specifying research topics (e.g., agriculture), the explosive increase of ES publications can give a false impression about MFA trends.

2.2. Ideological bases of MFA and ES

The ideas and concepts of MFA and ES do not originate independently. Their historical relationships are reflected in the evolving meaning bestowed on the term "function" in the two disciplines, which base their ideologies on the provision mechanisms of multifunctionality and ecosystem services. These basic distinctions largely influence the choice of scientific questions and methodologies, which are expressed as a preference for farm-centred approaches versus service-centred approaches, respectively.

2.2.1. Historical use of the term "function" in MFA and ES

Early literature used the term "function" to refer to the provision of goods and services by the natural environment. For example, Holdren and Ehrlich (1974) used the term "public-service functions," and de Groot (1987) proposed the concept of "environmental/natural function." These publications demonstrate a common origin of MFA and ES. However, the ES scientific community considers that "function" more appropriately defines the ecosystem capacity to provide services (Haines-Young and Potschin, 2010), and some use the term to describe the internal functioning of ecosystems, such as energy flux and nutrient recycling, or as a synonym for "ecosystem process" (de Groot et al., 2002; Wallace, 2007). The MFA community uses "function" or "land function" to describe the provision of goods and services by "land systems," which include the natural environment and human activities (e.g., OECD, 2001; Jongeneel et al., 2008; Verburg et al., 2009; Moon and Griffith, 2011). The MFA community developed different interpretations and approaches to research and policy making compared with those of the ES community.

It is noteworthy that there are two special groups. One group uses multifunctionality for "ecosystem function" or "landscape function", which is defined as the ecosystem or landscape capacity to provide goods and services; this group includes ES community researchers (e.g., Willemen et al., 2008; Kienast et al., 2009; de Groot et al., 2010). The other group considers "ecosystem services/environmental services" as outputs of a multifunctional agricultural system such as a farm (e.g., Randall, 2007; Jordan and Warner, 2010; Raudsepp-Hearne et al, 2010; Andersen et al., 2013).

2.2.2. Provision mechanisms of MFA and ES

MFA interprets the mechanism of multifunctionality using joint-production models, and identifies three sources of jointness as technical interdependencies, non-allocable inputs, and allocable inputs at a fixed level (OECD, 2001; van Huylenbroeck et al., 2007). ES explains the "production chain" of ecosystem services with respect to ecosystem-service cascades that include the following stages: ecosystem structure and process, function (capability to provide services), service, benefit, and value (Haines-Young and Potschin, 2010, de Groot et al., 2010). Precise distinctions between process, function, service, and benefit are still debated (Jax, 2005, de Groot et al., 2010). In agricultural research, different interpretations of MFA and ES provision mechanisms lead to further differences in understanding the roles of farming activities, ecosystems, and the range of functions and ecosystem services (Fig. 1-1).

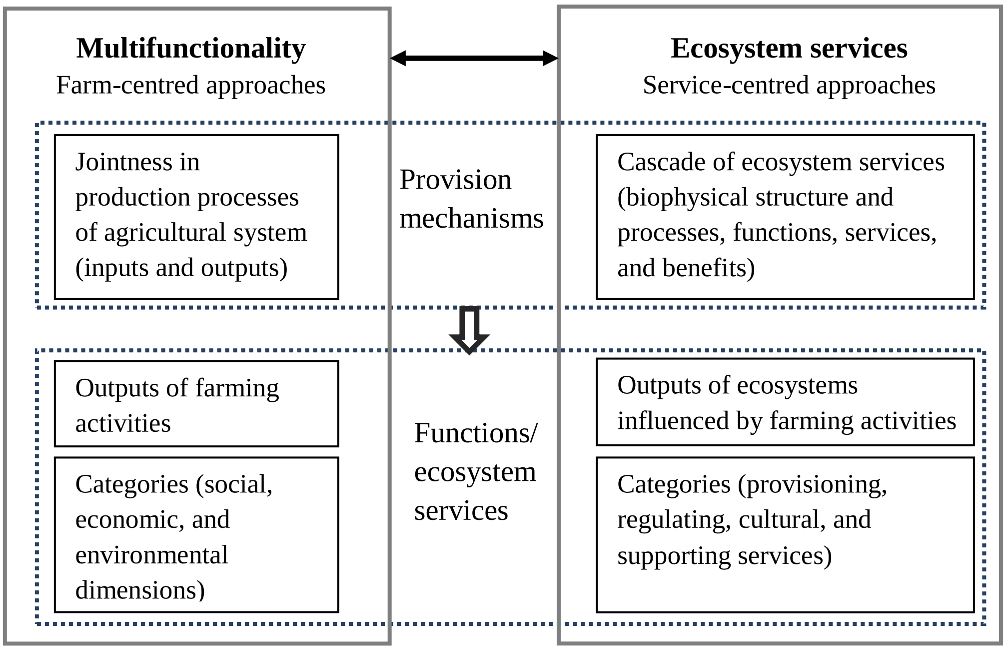


Fig. 1- 1. Fundamental differences between multifunctional agriculture and ecosystem services in agricultural research. Different provision models describe the roles of farming activities, ecosystems, and the range of functions and ecosystem services. MFA research favours farm-centred approaches, whereas ES research favours service-centred approaches.

The provision of goods and services in MFA is a direct result of agricultural activities, whereas in ES it is a direct result of ecosystems that are influenced by farming activities. Farming activities are external drivers that modify, improve, or diminish the ES provision capacity of agroecosystems (Dale and Polasky, 2007; Zhang et al., 2007; Power, 2010). Ecosystem structures and processes that are generated by biotic/abiotic interactions are the foundation of ES provisions, but are not always addressed in MFA analyses. Theoretically, industrial pig farming can be discussed within the framework of MFA, but not within the framework of ES. However, it is rare to focus on these systems in MFA research, because most functions depend on ecosystems and the maintenance of biodiversity, soil fertility and landscape quality.

Functions and ecosystem services categories are not coincident. MFA functions include farming’s environmental contributions including biodiversity and climate regulation, and contributions to rural cohesion and vitality, food security and safety, and animal welfare (OECD, 2001; Simoncini, 2009). ES functions include provisioning services, regulating services, cultural services, and supporting services according to the most widely accepted classification of MEA (2003). Poverty reduction is not an ecosystem service, although it is frequently discussed in ES research; it is a contribution of certain ecosystem services to human well-being (MEA, 2005; Pagiola et al., 2005). The function of food security includes agricultural food production and public access to sufficient, safe, and nutritious food (OECD, 2001). Food security is within the domain of human well-being in ES research (MEA, 2005).

2.2.3 Farm-centred approaches versus service-centred approaches

MFA research uses farm-level joint-production models to seek strategies that maximize food production and environmental outputs such as biodiversity, or minimize negative outputs such as pollution (Wossink et al., 2001; Buysse et al., 2007). Multifunctional agricultural transition is analysed at the farm level (Wilson, 2008). At the national and international levels, MFA usually denotes the relationships between agriculture sector and the environment (OECD, 2001), and has indirect influences that are mediated at local levels (Wilson, 2009). ES research prefers service-centred approaches supported by the cascade model. The research scale does not depend on the scope of agricultural exploitation, but on the ecological and institutional scales required to provide ES. Therefore, water-quality regulation or storm-peak mitigation services are sometimes assessed based on biophysical models of the related ecosystem structures and processes (Nelson et al., 2009; Johnson et al., 2012). Services such as pollination and biological pest control are important inputs to the farming system; they are extensively investigated in ES research (e.g., Losey and Vaughan, 2006; Sandhu et al., 2008; Schulp et al., 2014), but rarely considered as MFA inputs because their provision is beyond the farm. MFA joint-production models consider land, labour, capital, and raw materials as inputs (e.g., van Huylenbroeck et al., 2007; Parra-López et al., 2008; Jordan et al., 2011).

MFA and ES are both anthropocentric concepts that focus on human benefits. Service-centred ES approaches attempt to identify beneficiaries, whereas farm-centred MFA approaches do not. Identification of beneficiaries is crucial for ES valuation, because ecological structures and processes are not translated into ecosystem services until directly or indirectly consumed by humans (de Groot et al., 2002; Boyd and Banzhaf, 2007; Costanza, 2010). MFA function refers to the provision of goods and services that "satisfy societal needs or demands" and the end consumer is also human (Wiggering et al., 2006), but researchers focus on what is produced or what is transformed in the agricultural system rather than identification of the end consumer.

2.3. Comparison of MFA and ES research approaches

Due to multidisciplinary approaches during the last decade, MFA and ES research share the following four goals: (1) identification and classification of functions/ES; (2) quantification, valuation, and mapping of functions/ES; (3) trade-offs and synergies among functions/ES; and (4) MFA design and ES management. The research approaches associated with each concept are developed separately, but exhibit important similarities and differences.

2.3.1. Identification and classification of functions/ecosystem services

MFA and ES communities have fiercely debated identification and classification problems, but with different focuses. MFA debates are primarily focused on the scope of functions, especially during the early conceptualization period. Different countries have different attitudes regarding whether agricultural functions include biodiversity, food security, rural employment, and animal welfare (European Commission, 1999; Bohman et al., 1999; OECD, 2001; Van Huylenbroeck et al., 2007). MFA research does not pursue precise classification systems due to the shifting scope of functions, and generally distinguishes between commodity and non-commodity outputs, or between economic, environmental, and social functions (e.g., Buysse et al., 2007; Gómez Sal and Gonzalez Garcia, 2007). By contrast, ES research is rooted in ecosystem benefits for humans, which provides additional clarity for the scope of ecosystem services. Disputes principally arise over specifications of functions, services, and benefits, which are key terms in the ES cascade. These disputes result in different classification systems, such as those of Costanza et al. (1997), de Groot et al. (2002), MEA (2003, 2005), Wallace (2007), Costanza (2008), Boyd and Banzhaf (2007), and the Common International Classification of Ecosystem Services (CICES) (Haines-Young et al., 2012).

Negative externalities, which are unavoidable issues in agriculture, pose greater challenges to ES classification systems. MFA research considers negative externalities as non-commodity outputs of agricultural activities [e.g., greenhouse gas emissions (Boody et al., 2005)], or considers the reduction of negative externalities as a function of environmental health [e.g., reducing nitrogen leaching from agriculture (Wiggering et al., 2006; Parra-López et al., 2008)]. ES research, rooted in ecosystems, considers negative externalities as ecosystem disservices such as habitat loss, nitrogen leaching, and pesticide poisoning of non-target species (Swinton et al., 2007; Zhang et al., 2007; Power, 2010). We argue that nitrogen leaching and other effects resulting from farming activities should not be labelled as ecosystem disservices. For example, nitrogen leaching is caused by overuse of mineral fertilizers that exceed plant requirements and ecosystem nitrogen-retention capacity (Spiertz, 2010).

2.3.2. Quantification, valuation, and mapping of functions/ecosystem services

Quantification, valuation, and mapping of functions/ES is important for subsequent trade-offs, planning and management, and policy making. This is recognised in MFA (Randall, 2002; Mittenzwei et al., 2007) and ES (Cowling et al., 2008; Banzhaf and Boyd, 2012; Viglizzo et al., 2012) research. Table 1-1 summarizes MFA and ES literature. We distinguish three quantification approaches, two valuation approaches, and six mapping objectives.

The three quantification research approaches in Table 1-1 represent increasing uncertainty tolerances. Because it is rarely possible to trace the functions/ES production chain, many researchers link it to land use, land characteristics, or biodiversity. Once the connections are established, simpler indicators such as forest area, grassland quality, or species redundancy can be used as efficient criteria for valuation, management, and policy making. Key challenges regarding economic valuation relate to non-market outputs valuation in both MFA and ES (Randall, 2002, 2007; Johnson et al., 2012).Mapping in MFA research (except for papers that map landscape functions) is usually performed at the farm level, illuminating the spatial characteristics of multiple functions by mapping land-use parcels and other elements. Mapping in ES research is usually performed on large scales that consider ES distributions calculated directly or indirectly from land use or land characteristics.

2.3.3. Trade-offs and synergies between functions/ecosystem services

ES and MFA research highlights trade-off analysis, which has two goals. The first is to understand the relationship among multiple functions/ES and choose appropriate land-use strategies that have win-win outcomes, such as a high provision of biodiversity and other ecosystem services (Nelson et al., 2009). The second is to understand the driver or important factors influencing the relationship between services and reconcile different functions/ES. For example, an increase in landscape structural complexity enhances biodiversity without reducing agricultural production (Sabatier et al., 2014).

Table 1-2 presents a summary of the approaches used in trade-off analyses. First, among the three types of trade-offs in Table 1-2, associations of biodiversity or habitat with other ecosystem services are more prevalent in ES research. Second, MFA and ES have different explanations for trade-off mechanisms; MFA uses the theory of jointness in agricultural production processes, and ES uses a typology of relations combing driver effects and interactions between ecosystem services. It is noteworthy that Brummel and Nelson (2014) suggested a system-level conception of MFA identifying not only the jointness between production and non-production benefits but also the interdependence of non-production benefits among themselves. Third, MFA and ES use different methods to investigate pairwise relations; MFA researchers use joint-production models, whereas ES researchers use spatial overlays, correlation analysis, and principle-component analysis (PCA). Finally, MFA and ES use radar and wind rose charts to represent trade-offs among multiple functions or ecosystem services. Either historical data or scenarios can be supports to trade-off analysis.

Table 1- 1 Summary of quantification, valuation, and mapping in multifunctional agriculture and ecosystem services research.

Approach/Objective	Multifunctional agriculture	Ecosystem services
Quantification		
Single function/ES quantification based on biophysical models	Boody et al., 2005; Vatn et al., 2006	Losey and Vaughan, 2006; Sandhu et al., 2008; Nelson et al., 2009; Johnson et al., 2012; Schulp et al., 2014
Single function/ES quantification based on direct or weighted indicators as approximations	Mittenzwei et al., 2007; Andersen et al., 2013	Troy and Wilson, 2006; Raudsepp-Hearne et al., 2010; Carreño et al., 2012
Multiple function/ES quantification based on expert ranking terms	Gómez Sal and Gonzalez Garcia, 2007	Burkhard et al., 2009
Valuation		
From the provision side, including production-cost, opportunity-cost, replacement-cost, or avoided-cost methods	Randall, 2002; Madureira et al., 2007	Losey and Vaughan, 2006; Sandhu et al., 2008; Johnson et al., 2012
From the demand side (i.e., the "willingness to pay"), obtained by revealed preference methods including the travel-cost, hedonic-price, and averting-behaviour methods, or by stated-preference methods including contingent valuation, conjoint analysis, choice experiments, and contingent ranking	Randall, 2002; Boody et al., 2005; Madureira et al., 2007	Takatsuka et al., 2005; Losey and Vaughan, 2006; Kallas et al., 2007; Moon and Griffith, 2011
Mapping		
Identification of ranges and hotspots	Gimona and van der Horst, 2007*; Willemen et al. 2008*; Lovell et al., 2010a	Chan et al., 2006; Troy and Wilson, 2006; Egoh et al., 2008; Burkhard et al., 2009; Sherrouse et al., 2011
Trade-offs	van Berkel and Verburg, 2011*	Naidoo et al., 2008; Raudsepp-Hearne et al., 2010
Demand-supply relationships	Pfeifer et al., 2009	Burkhard et al., 2012 ; Schulp et al., 2014
Benefit-cost relationships	–	Naidoo and Ricketts, 2006
Land-use optimization/landscape design	Meyer and Grabaum, 2008*; Lovell et al., 2010b	–
Scenario analysis	van Mansvelt et al., 1998; Kienast et al., 2009*; Wolf and Meyer, 2010*; van Berkel et al., 2011	Nelson et al., 2009

*Research that maps landscape functions.

Table 1- 2 A summary of trade-off analyses in multifunctional agriculture and ecosystem services research.

Approach	Multifunctional agriculture	Ecosystem services
Type of trade-off and synergy		
Between commodity outputs (economic benefits) and non-commodity outputs (non-market ES)	OECD, 2001; Wossink et al., 2001; Wiggering et al., 2006; Buysse et al., 2007; Andersen et al., 2013	Viglizzo and Frank, 2006; Steffan-Dewenter et al., 2007; Carreño et al., 2012
Between biodiversity or habitat conservation and other ES	–	Chan et al., 2006; Smukler et al., 2010; Maes et al., 2012
Among multiple functions/ES	Holmes, 2006; Gómez Sal and Gonzalez Garcia, 2007	Raudsepp-Hearne et al., 2010
Mechanisms of trade-offs		
A typology of relationships between ES based on driver effects and interactions between services	–	Bennett et al., 2009
Three types of jointness between multiple outputs from agricultural systems	OECD, 2001 (see section 2.2.2)	–
Pairwise relations analyses		
Spatial overlay	–	Swallow et al., 2009; Goldstein et al., 2012
Correlation analysis	–	Raudsepp-Hearne et al., 2010; ; Carreño et al., 2012
Principle-component analysis	–	Raudsepp-Hearne et al., 2010; Maes et al., 2012
Comparing changes following a third variable (e.g., spatial complexity of rural landscapes or canopy cover)	–	Steffan-Dewenter et al., 2007; Laterra et al., 2012
Joint-production models	Wossink et al., 2001; Wiggering et al., 2006; Buysse et al., 2007	–
Trade-offs among multiple functions/ES		
Radar chart or wind-rose method	Gómez Sal and Gonzalez Garcia, 2007; Andersen et al., 2013	Raudsepp-Hearme et al., 2010; de Groot et al., 2010
Data support		
(Multi-year) historical data	Andersen et al., 2013	Viglizzo and Frank, 2006; Swallow et al., 2009; Carreño et al., 2012
Future land-use scenarios	Boody et al., 2005; Mittenzwei et al., 2007	Chan et al., 2006; Nelson et al., 2009; Smukler et al., 2010; Goldstein et al., 2012

2.3.4. MFA design and ES management

MFA and ES have become standard approaches for land-use or ecosystem management problems, such as arrangement of vegetation bands or field margins (Groot et al., 2007, 2010; Steingröver et al., 2010; Ryan et al., 2010; Meyer et al., 2012; Christen and Dalgaard, 2013), design of vegetative buffers around aquatic habitats or restauration of wetlands to replace traditionally engineered systems (Trepel, 2010; Díaz et al., 2012, Stutter et al., 2012), land-use planning (Brosi et al., 2008; Grêt-Regamey et al., 2008; Meyer and Grabaum, 2008; Jordan et al., 2011; Aubry et al., 2012; Tassinari et al., 2013), and farming practices management that incorporates agro-environmental measures (Simoncini, 2009; Rega and Spaziante, 2013).

MFA or ES strategies produce both private benefits and public goods which have different influences on farmers' motivation. Farm-centred MFA researches distinguish on-farm effects as private benefits and off-farm effects as public goods; they emphasize the private benefits such as more enjoyable work in driving farmer's decision, apart from public supports for off-farm positive externalities (Belletti et al., 2002; Brummel and Nelson, 2014). Public supports for MFA are often criticized for market-distortion effects because they do not sufficiently decouple public goods production from food production (Potter and Burney, 2002; Bonnal et al., 2012). Service-centred PES (Payments for Ecosystem Services) mechanism, to the contrary, is interesting for its efficiency in solving public goods problem since it requires identification of the provider and beneficiaries of ES (Pagiola et al., 2005). However, monetary PES programs and even the ES concept itself are suffering a growing criticism of improper commodification of nature, for example damaging farmers' intrinsic motivation (Farley and Costanza, 2010). A growing literature suggests that designing market or public incentives should depend on the characteristics of private or public benefits of the ecosystems and services in question (Farley and Costanza, 2010; Ma and Swinton, 2011). Comparatively, MFA strategy is more capable of considering social and mental benefits in driving farmers' transition. Combining MFA and ES will facilitate the integration of the contributions from ecosystems in our social-economic system, and the formulation of more effective incentives for public goods.

3. Towards an integrated research framework for multifunctional agriculture and ecosystem services

Although MFA and ES communities have expanded their research scope, each paradigm faces challenges from specific agricultural problems. For example, neither MFA nor ES has clearly understood the mechanisms that deliver multiple functions or ecosystem services from agriculture. MFA considers agriculture as an economic activity; the paradigm falls short in elucidating the underlying biophysical processes and developing biophysical models to evaluate agricultural outputs. MFA usually adopts indicator-based valuation methods (e.g., Andersen et al., 2013). The ES paradigm falls short for highly managed agroecosystems; it has difficulties distinguishing between natural and anthropogenic effects, which leads to abuse of the term "ecosystem disservices" (e.g., Zhang et al., 2007). ES valuation methodology can be too abstract for practical use without combining social, economic, and ecological dimensions. To meet these challenges and better operationalize both concepts for sustainable agricultural strategies, we suggest that the two communities deepen their mutual understanding and establish effective cooperation. To create a platform for this endeavour, we propose dialog on two specific questions and an integrated research framework.

3.1. Bundle of ES and spectrum of MFA

Two mutual ideas can open a dialog for communication between MFA and ES communities. Raudsepp-Hearme et al. (2010) used the idea of a "bundle of ecosystem services" to describe sets of services that appear together repeatedly across landscapes representing specific land-use modes, such as feedlot agriculture, corn-soy agriculture, and exurban. The idea of "multifunctional agriculture spectrum" was used by Wilson (2001, 2008) and Holmes (2006) to categorize agricultural occupancy modes at the farm level, and to classify these modes along a spectrum from weak to strong multifunctionality. These two ideas address links between particular land-occupancy modes and combinations of functions/ES; the former addresses spatial patterns, whereas the latter addresses evolution over time. It would be useful to integrate the two approaches. Accurate descriptions of ecosystem services bundles can help identify different MFA configurations; understanding trade-offs and synergies between two or more functions/services can help explain nonlinear MFA transitions (Wilson, 2008). A "multifunctional agriculture spectrum" analysis can help identify relationships among different agricultural systems characterized by particular bundles of ecosystem services.

3.2. Land-sharing versus land-sparing

ES research discusses land-sharing and land-sparing strategies, whereas MFA research discusses multifunctional agriculture and multifunctional landscapes. These discussions consider the validity of maintaining multiple functions/ES on the same land. Wildlife-friendly farming using a land-sharing strategy (provision of multiple services from one land parcel at intermediate levels) may improve farmland biodiversity, whereas intensive farming using a land-sparing strategy (single-service prioritization) may enable permanent preservation of adjacent species-rich areas. The appropriate strategy will differ for different areas (Green et al., 2005; Fischer et al., 2008; Maskell et al., 2013). In MFA research, it is not necessarily better to design individual multifunctional farming systems. Multifunctional landscape strategies are encouraged, which produce mosaic connections at the territorial level among different specialized farming systems and non-agricultural elements such as hedgerow networks (Vereijken, 2002; van Huylenbroeck et al., 2007; Simoncini, 2009; Jordan et al., 2011). Communications between MFA and ES can improve knowledge of application conditions associated with each strategy. ES research has advantages at the landscape level because the scale is determined by spatial characteristics of the ES cascade and is not restricted within the farm. MFA research has advantages for farm-level optimization analysis combining economic, social, and environmental dimensions. Farm-level models are less common in ES research, and are primarily concerned with ecological aspects of agroecosystems (e.g., Von Haaren et al., 2012; Kremen et al., 2012).

3.3. An integrated conceptual framework of MFA and ES

A reasonable and useful approach toward integration is to consider multiple ecosystem services and disservices to and from agriculture as inputs and outputs in the farm-based joint-production model of MFA. Then, by analysing each service and interactions based on ES cascades, researchers can better evaluate inputs and outputs and optimize farming strategies. We propose a conceptual framework integrating ES and MFA (Fig. 1-2). This framework will hopefully promote "ecological intensification," which replaces anthropogenic inputs with natural services to maintain food security (Bommarco et al., 2013). For simplicity, we assume that croplands are surrounded by semi-natural habitats such as non-crop patches and sown flower strips. Farm is the principle decision unit in the agricultural landscape. Farmers manage non-crop elements such as field margins and hedgerow networks, so the extent of the farm may encompass some surrounding semi-natural habitats. Other entities are urban consumers/beneficiaries and downstream areas negatively affected by agricultural runoff through hydrological networks.

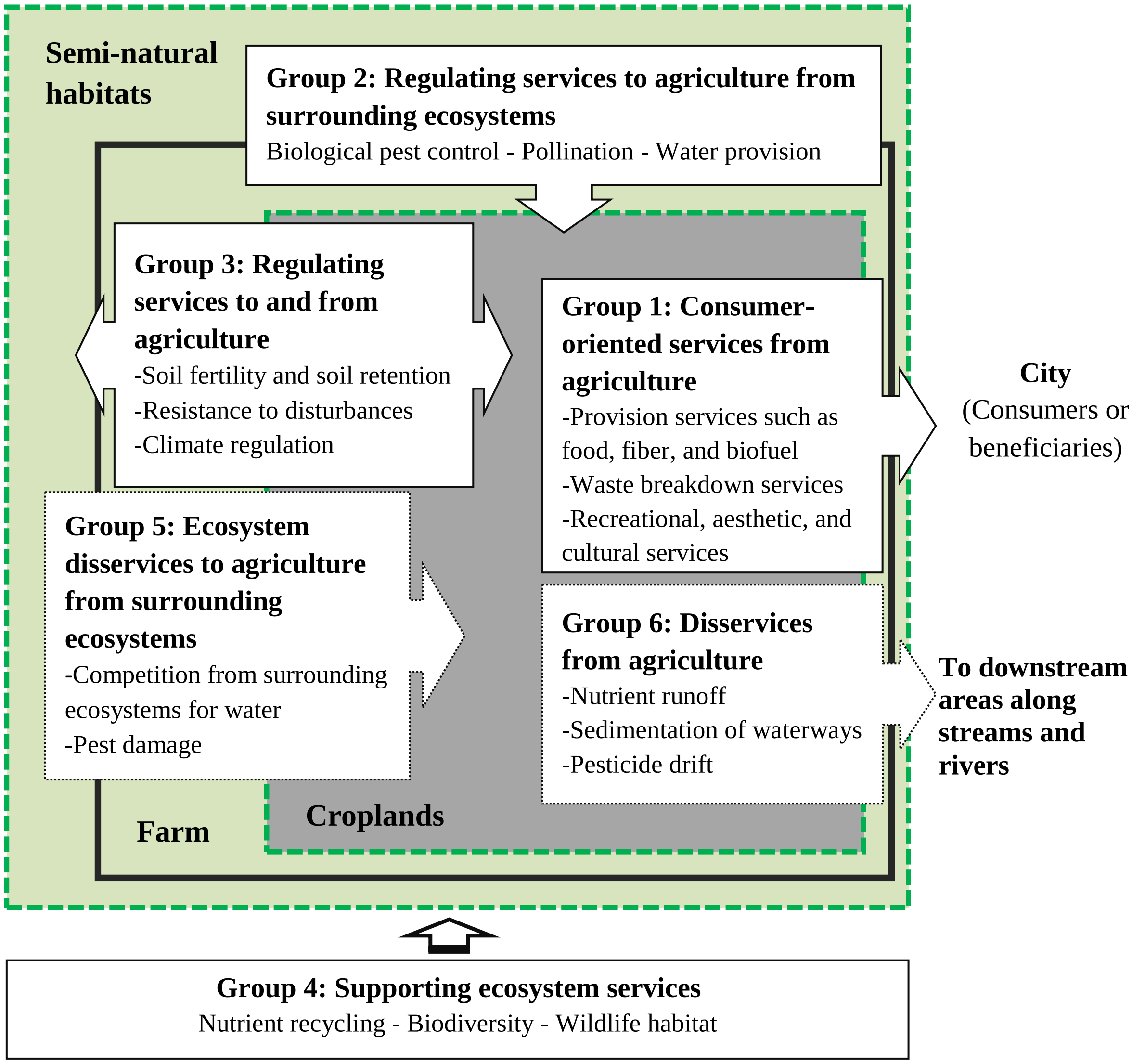


Fig. 1- 2. Integrated framework of multifunctional agriculture and ecosystem services. The framework distinguishes six groups of ecosystem services and disservices, assuming that croplands (grey) are surrounded by semi-natural habitats (green), farm is the principle decision unit, and farm may encompass some surrounding semi-natural habitats.

Based on previous research (e.g., Zhang et al., 2007; Power, 2010; Ma and Swinton, 2011; Firbank et al., 2013), we distinguish six groups of services and disservices according to their relationship with agriculture (to/from agriculture), spatial characteristics (on-site/off-site), categories according to MEA typology (MEA, 2003), and spatial scales. We use the term "disservices" to designate negative effects of farming activities such as nitrogen leaching and pesticide drift, and the term "ecosystem disservices" to designate negative effects from ecosystem functions such as pest damage and competition for water and sunlight from surrounding ecosystems. Farmers may have different motivations associated with each group. Subgroups can be identified within each group (e.g., based on scale). The six groups of ecosystem services/disservices are as follows:

Group 1: Consumer-oriented services from agriculture, including food, fibre, biofuel production, waste-breakdown services, recreational, aesthetic, and cultural services. These services are usually provided to local or global markets and consumers outside of the agricultural landscape. Incentives such as payments are needed to motivate farmers to provide them. There are no payments to farmers for recycling sewage sludge in many countries, because farmers benefit from organic-waste fertilizers. Recreational, aesthetic, and cultural services are special, because farmers are providers and beneficiaries. The spatial scales of these services depend on the consumers served and range from local to regional and global.

Group 2: Regulating services to agriculture from surrounding ecosystems, including biological pest control, pollination, and water provision. These are important ES provided by surrounding or upland ecosystems that farmers may not be aware of and take for granted, or substitute with measures such as pesticides and water pumping from distant sources. These services act at the field and landscape scales.

Group 3: Regulating services to and from agriculture, including soil fertility, soil retention, resistance to disturbance, and climate regulation. These services are very important for agricultural production. They are maintained by activities of flora and fauna in and around the croplands, and are supported by the landscape structure. They are required by other ecosystems at the landscape level, and can be positively or negatively influenced by farming activities. For example, appropriate farming practices improve soil fertilization and retention, and enhance the ability of the agroecosystem to resist storm damage (Philpott et al., 2008), whereas over-intensified farming practices cause soil degradation, erosion, and lands that are less resilient to floods. Because these services profoundly affect the farm, farmers have a direct interest in proper management (Zhang et al., 2007). Climate regulation includes local climate regulation (Ryan et al., 2010), carbon sequestration, and emission, which is an important factor in global climate change. The motivation for farmers to increase services (carbon sequestration) and reduce disservices (carbon emission) that function on a global scale tends to be weak unless there are national or international incentives (e.g., a carbon market). Except for services/disservices involving carbon balance, these services act at the field and landscape scales.

Group 4: Supporting ecosystem services in agricultural landscapes, including nutrient recycling and conservation of biodiversity and habitat. These are essential supporting services for the provision of other ES. For example, nutrient recycling enhances soil fertility, and biodiversity and habitat conservation support biological pest control and pollination. These supporting services are important for surrounding ecosystems, and agriculture has been widely criticized for damaging these services. These services act at the field and landscape scales.

Group 5: Ecosystem disservices to agriculture, including competition for water and pest damage. These disservices to agricultural production originate from the surrounding ecosystems. Surrounding ecosystems compete for water, sunlight, nutrients, and pollination. They are sources of pests and weeds, so farmers are reluctant to keep non-agricultural patches (e.g., fallow lands) among planted parcels in intensified farming systems. These disservices act at the field and landscape scales.

Group 6: Agricultural disservices to surrounding ecosystems, including nutrient runoff, sedimentation of waterways, and pesticide drift. These are off-site disservices from agriculture. Their negative effects are manifested at downstream areas along hydrological networks. Watershed-scale incentives are required to motivate farmers to adopt appropriate measures to reduce these disservices (e.g., agro-environmental schemes and watershed payments for ES).

4. Conclusions

MFA and ES are closely related strategies in agricultural research. They aim to recognize and manage multiple services and disservices from agriculture beyond production needs. However, MFA and ES differentially interpret the provision of these functions/services as results of farming activities or ecosystem functions, respectively. MFA research uses farm-centred approaches supported by the joint-production model, and analyses the problem using inputs and outputs. ES research uses service-centred approaches and analyses the problem using the ES cascade. These distinctions result in similarities and differences in MFA and ES research approaches. Comparative reviews suggest that there is great value in pooling the ideas and approaches of MFA and ES.

We hope that the proposed integrated framework will facilitate attempts to increase communication between MFA and ES communities. We suggest the following key points for future communication: (1) highlight the role of farm as an important decision unit; (2) harness ecosystem services to replace anthropogenic inputs; (3) deepen the understanding of agricultural outputs, especially by distinguishing ecosystem services/disservices and results of human activities; and (4) combine the ecological, social, and economic dimensions. Future research should examine if the framework can be readily adapted for modelling particular problems in agricultural management, such as recycling of urban organic waste. Integration of MFA and ES will improve their applications in operational use and contribute to policy-making for sustainable agricultural development.

Chapter 2

Evolution of agricultural land use in the Ile-de-France Region

1. Study area and methods

1.1. Study area

Ile-de-France Region covers an area of 12 012 km^2, representing 2.2% of the French metropolitan land. It is the most densely populated region of France. According to the French National Institute for Statistics and Economic Studies (INSEE, 2015), the regional population keeps on growing and has arrived 12 005 077 in 2014, accounting for 18.8% of the French metropolitan population. The idea of a regional planning to relieve the congestion of Paris agglomeration first emerged in the PROST project in 1930s, and was officially confirmed by the creation of the Paris Region in 1961. The Region released its first master plan in 1965 (Schémas Directeur d'Aménagement et d'Urbanisme, SDAU) (Cottour, 2008). It reused its historical name of "Ile-de-France" from 1976.

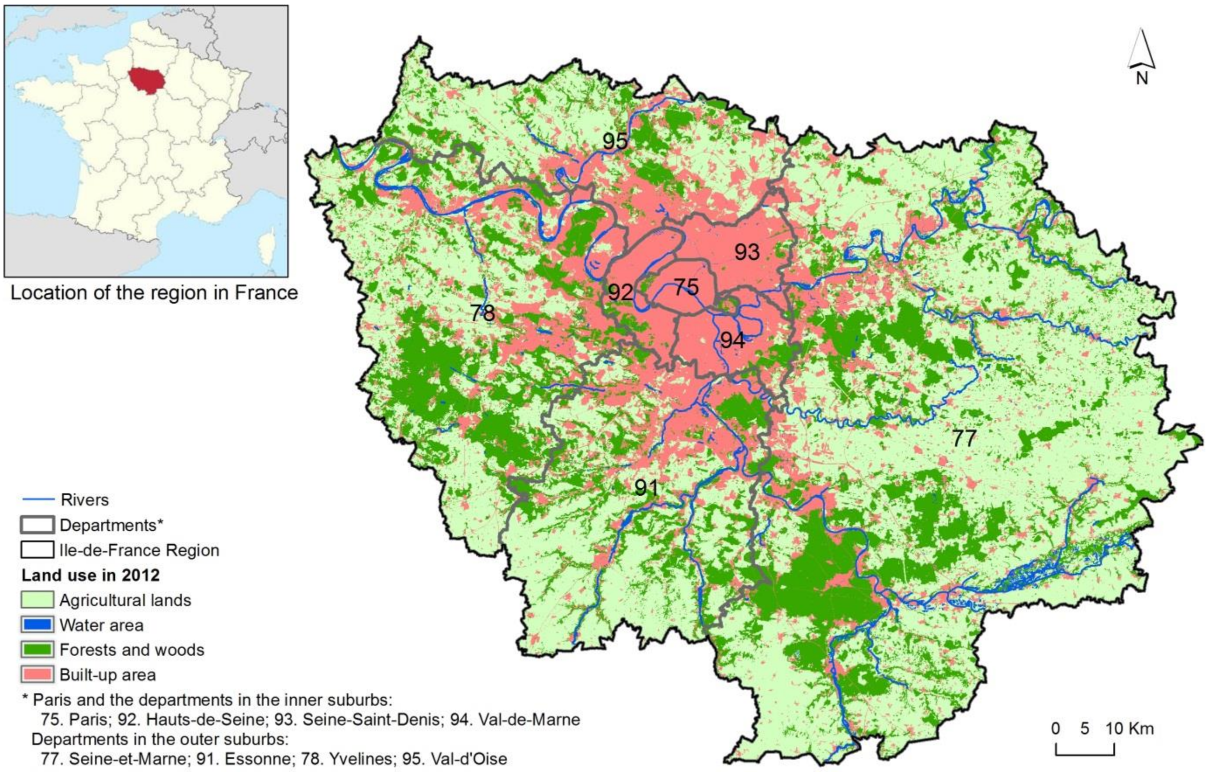


Fig. 2- 1. Main geographical features of the study area

Located in the Seine basin in the north of France (Fig. 2-1), Ile-de-France Region has a temperate Atlantic climate, characterized by a relatively narrow annual temperature range and an evenly dispersed precipitation throughout the year. The monthly average temperature ranges from 2.5 °C in

January to 20.5 °C in July. The average annual precipitation is between 550 and 800 mm. The average sunshine duration is between 1 700 and 1 800 hours per year. The landform is composed of plains and plateaus carved by deep or shallow valleys. This results in a great variation in soil properties and agricultural potential at the local scale (DRIAF and IAURIF, 2004). Generally, the vast plains and plateaus have a deep silt loam soil favorable for arable farming, whereas lands on the slopes and in the valleys have some limitations, for example poor fertility, stony upper layers, clay texture difficult for cultivation, and problems with water storage or natural drainage.

Originating from the Gallo-Roman time and being at the forefront of agricultural modernization since 18th century, agriculture in the region has been fully developed and demonstrates a strong dual pattern (Phlipponeau, 1956). The plains and plateaus are occupied by large size fields of cereal, oilseed and protein crops, as well as industrial crops, e.g. sugar beets. Forests persist only at areas with infertile sandy soil, such as Fontainebleau. Lands on the slopes and in the valleys, originally dedicated to forests, meadows or fallow, have also been substantially developed with drainage or irrigation technics. These lands are occupied by labor-demanding small size exploitations of specialty cultures, such as vegetables, fruits, flowers, and livestock. Substantial agricultural lands were consumed by urban construction in the last century (Cottour, 2008). Urban agglomeration occupies almost entirely the three departments in the inner suburbs and expands towards other departments in the outer suburbs (Fig.2-1). High mobility of agricultural products has greatly changed the relations between peri-urban agriculture and the city. Agricultural lands got the role as open spaces recognized by the master plans from 1970s. Then since 2000s, initiations for a multifunctional agriculture reclaim the function of food security, biodiversity conservation, and adaptation to climate change. There is a rising motivation to preserve agricultural lands in the regional planning.

1.2. Methods

The evolution of agricultural lands in Ile-de-France was analyzed through three steps: The first step investigated the consumption of cultivable lands by urban construction from 1900. Cultivable lands include utilized agricultural lands and uncultivated lands, e.g. abandoned farmlands covered by grass or shrubs. Urban construction normally means permanent loss of agricultural lands, so consumption of cultivable lands is critic for the regional agricultural potential. The spatial analysis used the multiple-year land use database MOS of the Institute of Management and Urbanism of Ile-de-France Region (IAURIF). MOS is a regular observation to regional land use pattern in every four or five years since 1982 based upon satellite images and aerial photos, and verifications by field visits. The latest land use data was that of 2012. IAURIF also adapted historical maps available from 18th century to the database, which made it possible to observe the long period evolution of the principal land use types. I set the starting point of the present analysis in 1900 considering the fact that Haussmann's renovation of Paris in late 19th century founded the actual limit of Paris city. The second phase of land use map available is for 1960. It was made by the National Geography Institute of France (IGN) in 1922, and revised in 1960. The land use map of 1900 and 1960 did not cover the entire region. For the periods when regular observation is available, I selected three phases: 1982, 1994 and 2012. IAURIF distinguished 6 categories of land use when adapted the historical maps and 11 for the modern ones. I concluded them into 4 categories for this analysis: cultivable lands, water area, forests or woods, and built-up area (including urban area, roads and airports).

The second step studied the change of utilized agricultural lands in the same period. "Utilized agricultural land" is the translation for the French term of "Surface Agricole Utile (SAU)" used in statistics to assess land tenure. SAU is declared by farmers as area used for agricultural production. It includes arable lands and permanent crops such as meadows and fruits. Among arable lands, fallow lands are intentionally set-aside for future cultivations. Changes of SAU can be consequences of urbanization but also transformation in the agricultural sector. In Ile-de-France Region, the two factors coupled and mutually interacted. This step of analysis principally used annual agricultural statistics (SAA) of Ile-de-France. SAA are available for 1906, 1929, the years from 1946 to 1969, and then the years from 1984 to 2014. So the general agricultural census (RGA) of 1979 was used as a supplement for the period of 1970s. The French statistics have modified several times their typology of agricultural lands during such a long period. I made some adjustments to find a typology that makes the data comparable throughout the period.

The third step compared the urban consumption of cultivable lands and the evolution of utilized agricultural lands, in order to distinguish the influences of urban pressure and agricultural modernization, especially their impacts on regional agricultural pattern. The spatial pattern was observed by comparing the RGA of 2000 and 2010 at municipal level.

The spatial analysis and mapping were carried out in ArcGIS 10.0. It should be reminded that the maps and statistical data across such a long period probably have widely varying accuracy. It was the trends rather than the exact numbers, which led to the formulating of the conclusions. Another problem is that the SAA use different technics and criteria from that of the RGA. For example, SAA count SAU as lands located within the geographical limits while RGA count SAU as lands cultivated by a farmer who registers himself within the geographical limits. It is highly possible that a farmer cultivate some lands in the neighboring municipality or even in the neighboring region. I avoided comparisons at a fine level for data from different sources. The trends turned out remarkable and the incertitude did not influence the conclusions. Reference to qualitative documents also helped to avoid the risk of making mistakes.

2. Results

2.1. Consumption of cultivable lands by urbanization

Results showed a net loss of cultivable lands from 1900 to 2012 in the Ile-de-France Region. According to Table 2-1, cultivable lands converted from other uses only compensated 3% of the loss towards other uses. 83.6% of the loss was caused by urbanization and 15.1% by forestation. Cultivable lands are the principal victim of urbanization, representing around 90% of the lands converted to new urban area. The proportion was even 96.6% during the period of 1960-1982 when the rapidest urbanization happened. I distinguish two phases regarding consumption of cultivable lands by urbanization: a first phase of continual urban extension before 1960s and a phase of peri-urbanization and sub-center construction since 1960s (Fig. 2-2).

2.1.1. Continual urban extension before 1960s

For the period from 1900 to 1960, data was available only for the central zone covering the major part of Paris agglomeration. 61 707 ha of cultivable lands were lost with an annual speed of 1029 ha/year. Regional planning of land use did not exist in this period and was only under discussion from 1940s (Cottour, 2008). Urban construction was spontaneously carried out in response to the outward migration of industries and consequent needs of new residences for workers. Reconstructions after the two World Wars undoubtedly strengthened the trends (Brunet, 1985). Cultivable lands closely surrounding the former limits of Paris agglomeration were all lost, first the extensive crops (e.g. wines, fruits in the open fields) then the intensive profitable ones (enclosed vegetable cultivation, flowers), according to Phlipponneau (1956). Fresh vegetables, fruits and other “specialty crops” suffered a great loss, because they had an important distribution in that zone in the previous period, for being able to directly reach the city center in accordance with the theory of Von Thunen (Phlipponneau, 1956; Sinclair, 1967).

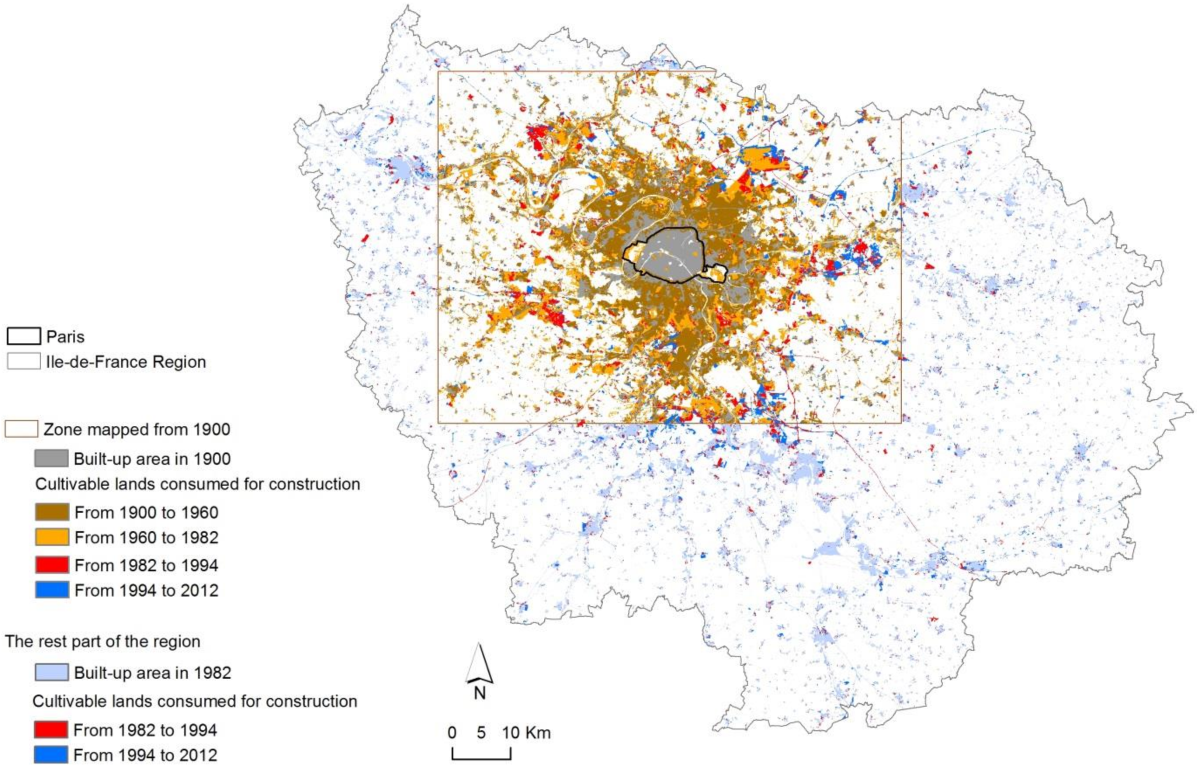


Fig. 2- 2. Cultivable lands consumed by urban construction in different periods from 1900 to 2012. Source: Land use database MOS of IAURIF

Table 2- 1 Changes of cultivable lands in different periods from 1900 to 2012

	The central zone mapped from 1900				**The rest part of the region**			
Time periods	Total area: 464 021 ha, covering the majority of the Paris agglomeration				Total area: 742 478 ha			
	Cultivable lands loss towards urbanization		Conversion between cultivable lands and other uses including urban use		Cultivable lands loss towards urbanization		Conversion between cultivable lands and other uses including urban use	
	Area of loss (ha)	Annual speed (ha/year)	Area converted to other uses (ha)	Area converted from other uses (ha)	Area of loss (ha)	Annual speed (ha/year)	Area converted to other uses (ha)	Area converted from other uses (ha)
1900-1960	61707	1029	82981	17004	-	-	-	-
1960-1982	59356	2698	72539	6900	-	-	-	-
1982-1994	19466	1622	20522	2586	7836	653	10006	4399
1994-2012	16202	900	18946	3242	10143	564	14767	4234
1900-2012[1]	142860	1276	170883	5627	-	-	-	-

Source: Land use database MOS of IAURIF. [1]The area of total loss and average annual speed for the period from 1900 to 2012 were obtained by comparing land use map of 1900 and that of 2012.

2.1.2. Peri-urbanization and sub-center construction since 1960s

The second phase of sub-center construction and peri-urbanization consumed cultivable lands at a much higher speed, especially at the beginning of this period. During 1960-1982 in the central zone for which data is available (Fig. 2-2), 59 356 ha of cultivable lands were lost with a speed of 2698 ha/year. First was the creation of 22 ZUP (Areas to be Urbanized in Priority) between 1958 and 1969 on the plateaus for the construction of collective public residences. Then projects of "New Town (Ville Nouvelle)" were initiated in order to construct five new sub-centers around Paris, namely, Marne-la-Vallée to the east, Cergy-Pontoise to the north-west, Saint-Quentin-en-Yvelines to the south-west, and Sénart and Évry to the south-east. All of them are located in15-30 km from Paris city. These projects are the main parts of a regional land use planning to guide the development of the Paris agglomeration. Construction of the new airport of Charles-de-Gaulle (CDG airport) to the north-east of Paris also consumed a lot of fertile cultivable lands (Bryant, 1973). During the following periods of 1982-1994 and 1994-2012, the trends continued but slowed down substantially. In the same zone as above, 19 466 ha of cultivable lands were lost during 1982-1994, with an annual speed of 1622 ha/year. The speed remarkably dropped to 900 ha/year during 1994-2012 and 16 202 ha of cultivable lands were lost. In the rest part of the region, 7836 ha and 10 143 ha of cultivable lands were lost during 1982-1994 and 1994-2012, respectively. The annual speed of loss were 653 ha/year and 564 ha/year, respectively. Construction of the sub-centers of Sénart and Evry was the most important consumption of cultivable lands in this part. The master plan (SDRIF) of 1994 fixed a limit for the consumption of cultivable lands as1750 ha/year. The average loss of 1464 ha/year in the whole region during 1994-2012 was well under this limit.

In this phase, consumption of cultivable lands was selective. Location of the sub-centers was determined by particular political consideration, mostly imposed on plateaus. Vast open-field cultivations such as cereal crops were lost immediately. Peri-urbanization driven by the rise of individual houses in search of nature from 1970s (Poulot and Rouyres, 2007; Charvet, 2003) mainly happened in the valleys and on the slopes, because of a lower land price and a better view of landscape. The specialty agricultural lands (e.g. vegetables, fruits, meadows) suffered great loss for that.

2.2. Evolution of agricultural land use

Ile-de-France region has 582 928 ha of utilized agricultural lands (SAU), accounting for 48.7% of the regional surface in 2014. Arable lands account for 90% to 95% of SAU of the region. Natural prairies account for 6% to 7%. The other permanent crops including fruit trees, wine and woody nurseries account for less than 2%.

2.2.1. Structure of arable lands

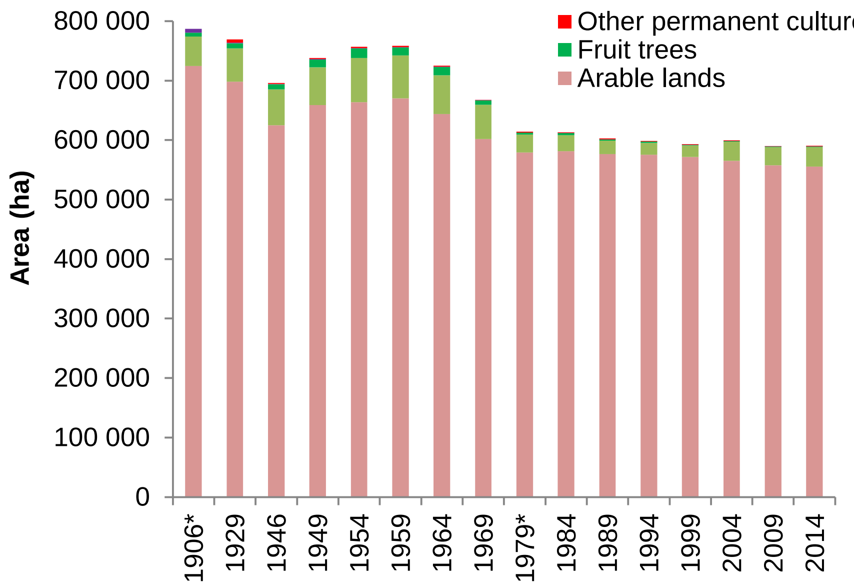
Within arable lands, more than 90% are large size open-field crops, which are called "Grande Culture" in the French literature, including COP crops (cereal crops, oilseeds and protein crops), sugar beets, potatoes, and other industrial crops. Fallow lands and forage crops are also presenting in the rotation system. There are two production systems in Grande Culture: one specialized in COP crops with or not industrial crops and one mixing crops and livestock. They are originated from a three-year-crop-rotation system adopted before the agricultural modernization in 18th century: lands were kept in fallow for one year ("jachères"), followed by two years of wheat production. The first year of fallow period was necessary for resting the land and carrying out practices to recover soil productivity. Then in 18th century, introduction of artificial meadows composed of alfalfa and clover promoted a mixed crop-livestock farming system and active use of animal manual to maintain soil fertility for cereal crops (Moriceau, 1994). Annual forage crops in the rotation system offered supplementary food for livestock. Fallow lands thus declined thereafter. The 20th century was marked by a gradual separation of crops and livestock. The use of mineral fertilization reduced the dependence of cropping systems on animal manure, while all kinds of motorized farming machines replaced the needs of animal labor. In fact, livestock largely disappeared in Ile-de-France because of multiple reasons as will be discussed in the following sections.

Another important part of arable lands is the fresh vegetable cultivation, though its area accounts for less than 1% since 2000. Vegetable cultivation was at its height in the last century and the climax was 4.1% in 1946. It includes the system of “maraîchage”, the intensive vegetable cultivation gardens invented by urban farmers in Paris city, and the “légume de plein champ”, the open-field vegetable cultivation. The “maraîchage” system moved to peri-urban areas when expelled by urban extension in the 18th and 19th century. Through the process of agricultural modernization in the 20th century, they became more and more close to the open-field vegetable cultivation. Both had an increased size and a higher degree of motorization. Fresh vegetables (e.g. lettuce) are now cultivated with cereal crops in the rotation system. In the French literature, the term “maraîchage” is also used to mean fresh vegetable cultivation in a general way. The statistical data did not distinguish the two systems for all the years. So the two systems were integrated as one category as fresh vegetable cultivation in this analysis. The present study is interested in the principal peri-urban agricultural land uses and ignored those agricultural activities with a minimum area, such as flower cultivation, medicine plants, tobacco, and diverse industrial crops, which counted normally less than 3% in total of the arable lands. The rest tiny proportion is composed by family gardens, which are cultivated for self-consumption. As there is a high incertitude in the statistics of family gardens, they are not discussed here. The photos in Fig.2-3 illustrate the principal farming systems in Ile-de-France region.

Fig. 2- 3. Principal farming systems in Ile-de-France region. a: large-scale open-field farming systems, b: intensive vegetable cultivation, c: mixed system of crops and livestock. Photos: searched from internet

2.2.2. Evolution of agricultural land use

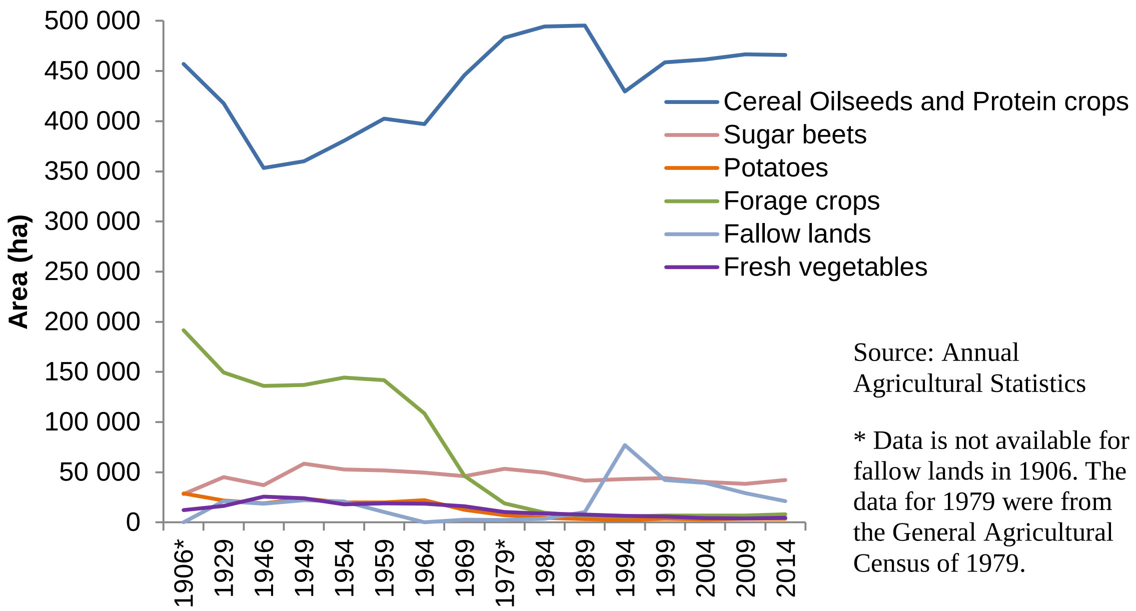
Fig. 2-4 and Fig.2-5 showed the evolution of utilized agricultural lands and evolution of the subcategories of arable lands from 1906 to 2014, respectively.



Source: Annual Agricultural Statistics

* The area of arable lands in 1906 indicated here is probably lower than the actual number, because no data is available for fruits area and fallow lands. The area of fruit trees in 1892 was used as estimation for 1906. The data for 1979 were from the General Agricultural Census of 1979.

Fig. 2- 4. Evolution of Utilised Agricultural Lands in Ile-de-France Region from 1906 to 2014



Source: Annual Agricultural Statistics

* Data is not available for fallow lands in 1906. The data for 1979 were from the General Agricultural Census of 1979.

Fig. 2- 5. Evolution of principal arable land uses in Ile-de-France Region from 1906 to 2014

From 1906 to 2014, the region lost 25.9% of SAU, which had a global trend of decrease except for the disturbance of the World Wars. The structure of SAU had a global trend of simplification from 1906 to 2014: arable lands, natural meadows, fruit trees and wine lost 23.3% (168 989 ha), 33.3% (16 534 ha), 84.9% (5 573 ha) and 99.6% (6 356 ha), respectively. COP crops and sugar beets increased 1.9% (8 737 ha) and 50% (14 117 ha), respectively. Potatoes, fresh vegetables and forage crops decreased 87.5% (25 296 ha), 63.1% (7 708 ha) and 95.8% (183 598 ha), respectively. The proportion of COP crops in arable lands increased from 63.1% to 83.9%. Area of wine and woody nurseries decreased to a small proportion of SAU at the beginning of the 20th century. The area of sugar beets kept relatively stable from 1950s, representing 7~ 8% of arable lands. Combining the change of different agricultural lands, three periods can be distinguished and correspond to the two phases of urbanization.

(1). From 1900 to 1950s

During the period of continual urban expansion from 1900 to 1950s (from 1906 to 1959), there saw a decrease of COP crops, forage crops and fallow lands and an increase of natural meadows, fruits, and vegetables. The COP crops, mainly composed by cereal crops, decreased 11.9% (54538 ha) in spite of a rally after the Second World War. Protein crops and oilseeds crops accounted for only a small proportion at that time. Area of potatoes decreased 31% (8947 ha). Forage crops decreased 26% (49911 ha). Fallow lands decreased 51.2% (10803 ha). Fresh vegetables increased 54.9% (6702 ha). Meadows increased 44.7% (22214 hectare) and fruits increased 101.6% (6662 ha).

(2). During 1960s and 1970s

During 1960s and 1970s (from 1959 to 1979), while the construction of sub-centers and peri-urbanization consumed strongly agricultural lands, there was a rapid increase of COP crops and decrease of all other types of agricultural uses. The area of COP crops increased 20% (83319 ha). Potatoes decreased 63.5% (12662 ha). Forage crops decreased 86.5% (122643 ha), among which artificial meadows decreased more than annual forage crops. Fallow lands decreased 77% (7928 ha). Fresh vegetables decreased 45.9% (8681 ha). Meadows decreased 58.2% (41847 ha) and fruits decreased 75.4% (9969 ha).

(3). From 1980s

From 1980s (from 1979 to 2014), when the process of peri-urbanization and construction of new sub-centers slowed down, SAU had a much slower decrease of 0.15% each year (894 ha/year). The composition of SAU became stable. The permanent meadows and fruit lands remained in a small proportion, taking up 3~6% and 0.2~0.6%, respectively. Arable lands strengthened its dominance in the regional agricultural land use up to 94~97%. The loss of arable lands accounted for 97% of the annual loss of SAU. The composition of arable lands also became stable, dominated by COP crops (80~86%), sugar beets (7~8%) and fallow lands (4~13%). The year of 1994 saw a sudden increase of fallow lands because of the Common Agricultural Policies (CAP) from 1992 encouraging set-aside of cereal lands. COP lands saw a sudden decrease commensurately. After 1994, the area of fallow lands decreased again, and the COP lands increased. Inside the COP crops, we saw a decrease of protein crops and an increase of oilseeds crops, principally rapes.

2.3. Comparison between urban consumption of cultivable lands and the evolution of utilized agricultural lands

2.3.1. Fast urban consumption of agricultural lands drives fast land abandonment

Comparison between the loss of SAU and cultivable lands in different periods shows that abandonment of agricultural lands was the most significant in the phase of rapid consumption of agricultural lands by urbanization (Table 2-2).

Table 2- 2 Comparison between the loss of SAU and cultivable lands in Ile-de-France

	Loss of SAU (ha)	Net loss of cultivable lands (ha)	Urban consumption of cultivable lands (ha)
From 1982 to 2012	30 016	49 780	53 647
From 1960 to 1982	142 400	Around 86 158	Less than 83 249
From 1900 to 1960	More than 56 239	Around 86 602	Less than 86 547

Sources: land use database MOS of IAURIF and annual agricultural statistics

Results imply opposite trends of farmland abandonment in the period of peri-urbanization and sub-center construction and the period from 1980s when urbanization slowed down.

(1). From 1982 to 2012

The statistics showed the whole region lost 30 016 ha of SAU. Analysis on land use maps showed that urbanization consumed 53 647 ha cultivable lands, and the net conversions from cultivable lands to other uses (i.e. forests, water area and urban uses) were 49 780 ha. Thus, the net loss of cultivable lands was higher than the loss of SAU in this period, which implies the large use of non-cultivated agricultural lands, e.g. abandoned farmlands. Urban consumption of cultivable lands was also remarkably higher than the loss of SAU. It suggests that from 1980s, there was important use of non-cultivated lands (e.g. former abandoned farmlands) for urbanization, or reuse of abandoned lands for agricultural activities to compensate the loss of SAU to urbanization.

(2). From 1960 to 1982

Land use maps from 1960 to 1982 only covered the majority of Paris agglomeration as shown in Fig. 2-2 (the central zone), so I supposed that the outer zone had the same trends as the central zone. Urban consumption of cultivable lands in the central zone during the period of 1960-1982 was 3.05 times of the consumption during the period of 1982-2012. I multiplied the urban consumption in the outer zone during the period of 1982-2012 with that rate, and finally got an estimation that in the whole region, urbanization consumed 83 249 ha of cultivable lands during the period of 1960-1982. In the same way, the estimation for the net conversions from cultivable lands to other uses (i.e. forests, water area and urban uses) in the whole region was 86158 ha during the period of 1960-1982. Because urbanization in the outer zone was less strong than in the central zone during 1960-1982, the regional urban consumption of cultivable lands should be less than 83 249 ha. Whereas, the statistical data showed SAU had a decrease of 142 400 ha in the same period. It is clear that the loss of SAU from 1960 to 1982 exceeded urban consumption of cultivable lands and probably the net loss of cultivable lands. It suggests that in the period of peri-urbanization and sub-center construction, there was a significant phenomenon of farmland abandonment in the region. The magnitude of the abandonment was greater than that of reusing these lands for urbanization or agricultural use.

(3). From 1900 to 1960

In the same way, the estimated net loss of cultivable lands from 1900 to 1960 was 86 602 ha, and the urban consumption of cultivable lands should be less than 86 547 ha. However, exact data is not available for the SAU of 1900. The estimated loss of SAU from 1906 to 1960 was 56 239 ha. Because the annual agricultural statistic in 1906 did not record the area of fallow lands, the area of fallow lands in 1929 was used for the year of 1906. Based upon the decreasing trend of SAU as shown in section

2.2.2 and a similar trend of fallow lands documented by Moriceau (1994), the loss of SAU from 1900 to 1960 should be more than 56 239 ha. Therefore, it is hard to say if the loss of SAU was less than the urban consumption of cultivable lands, but at least, the phenomenon of farmland abandonment was not that important in this period of continual urbanization.

Thus, the regression of agricultural lands in the zone close to urban agglomeration resulted from not only the direct loss by urban consumption, but also land abandonment. When the continual urban extension expelled fresh vegetables and fruit cultivation, there were important reinstallations of these systems in peri-urban valleys. Evidences were documented in literature. For example, Phlipponneau (1956)'s study revealed that peri-urban lands of fruits and wines were purchased by newly moving-in vegetable farmers. However, in the phase of sub-center construction and peri-urbanization since 1960s, it was difficult for reinstallation of fresh vegetable cultivation in the valleys. Expansion of individual houses consumed a part of spaces suitable for vegetable cultivation, and the new peri-urban residents also had higher demand for environmental quality which created obstacles to farmers, such as objections to using organic waste and pesticides.

2.3.2. Peri-urban agricultural land use pattern under urban influences

The pattern of the remaining agricultural lands in the outer suburbs was determined by the coupling of urban influences and agricultural transformation. Urban influences are becoming the predominant factor. Fig.2-6-1 and Fig.2-6-2 present the spatial distribution of the principal utilized agricultural lands in Ile-de-France in 2000 and 2010, including cereal crops, oilseeds crops, sugar beets, forage crops and meadows, as well as fresh vegetable cultivations. Fig. 2-7 presents the distribution of animal breeding in 2000 and 2010. The results were overlaid with the limits of "Régions Agricoles (Agricultural Regions)"defined in 1956. The "Régions Agricoles" of France were delineated based upon physical and economic criteria as relatively homogeneous regions and within such a region, farmers had similar agricultural activities or production systems.

Cereal crops are the dominant crops in the region and distribute equivalently on the remaining farmlands. The oilseed crops have similar pattern except for in the zone of Yvelines in the west and the zone of Brie laitière in the east. There are mainly three zones for the production of sugar beets: Goële-et-Multien/Vielle France in the north, Gâtinais in the south and the zone of Brie française-Brie Centrale-Brie Champenoise in the east (Agreste, 2013a; Petit, 2013). In fact, rape and sugar beet are often used as starter crops in the rotation systems, so the two crops are in competition depending on farmers' choice. The distribution of their production zones do not coincide. Since agro-industry has largely degraded in Ile-de-France, sugar beets and other industrial crops have to rely on factories in the neighboring regions (Poulot and Rouyres, 2004). Those factories are usually engaged in large-size conventional chains and are not interested in organic agriculture. According to the study of Petit (2013), organic farms appeared seldom in the municipalities with an important area of sugar beets. We may assume that sugar beets are usually the typical element of a highly productive and motorized conventional farming system. Cereal crops now are also more and more linked to the neighboring regions for the purpose to facilitate harvesting and processing.

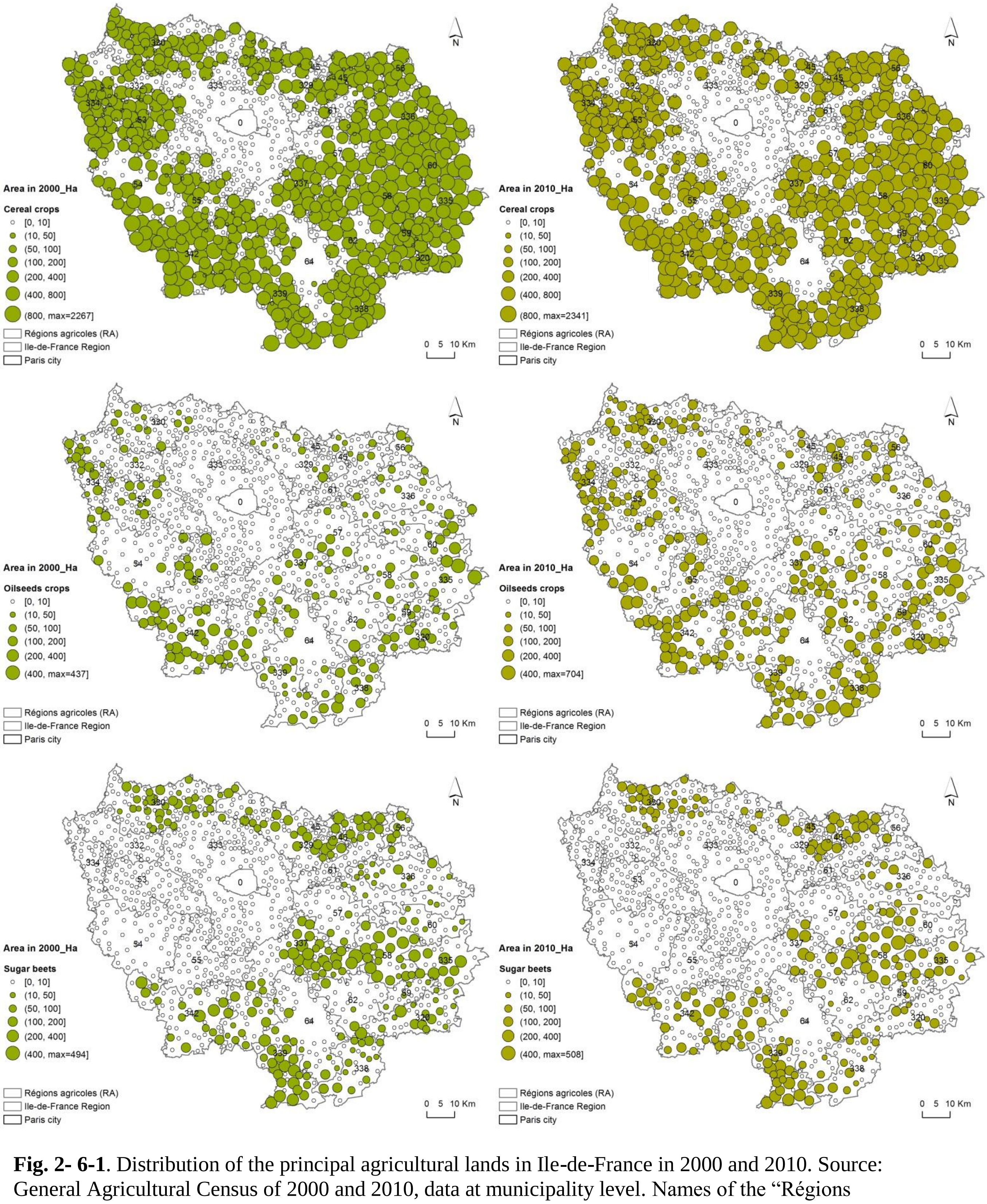


Fig. 2- 6-1. Distribution of the principal agricultural lands in Ile-de-France in 2000 and 2010. Source: General Agricultural Census of 2000 and 2010, data at municipality level. Names of the “Régions Agricoles”:45. Butte de Dammartin; 53. Plaine deVersailles; 54. Yvelines; 55. Hurepoix; 56. Orxois; 57. Brie boisée; 58. Brie Centrale; 59. Montois; 60. Brie Est; 61. Vallées de la Marne et du Morin; 62. Brie humide; 64. Pays de Bière et forêt de Fontainebleau; 320. Bassée; 329. Goële et Multien; 330. Vexin; 332. Vallée de la Seine; 333. Ceinture de Paris; 334. Drouais; 335. Brie Champenoise; 336. Brie laitière; 337. Brie française; 338. Bocage Gâtinais; 339. Gâtinais; 342. Beauce.

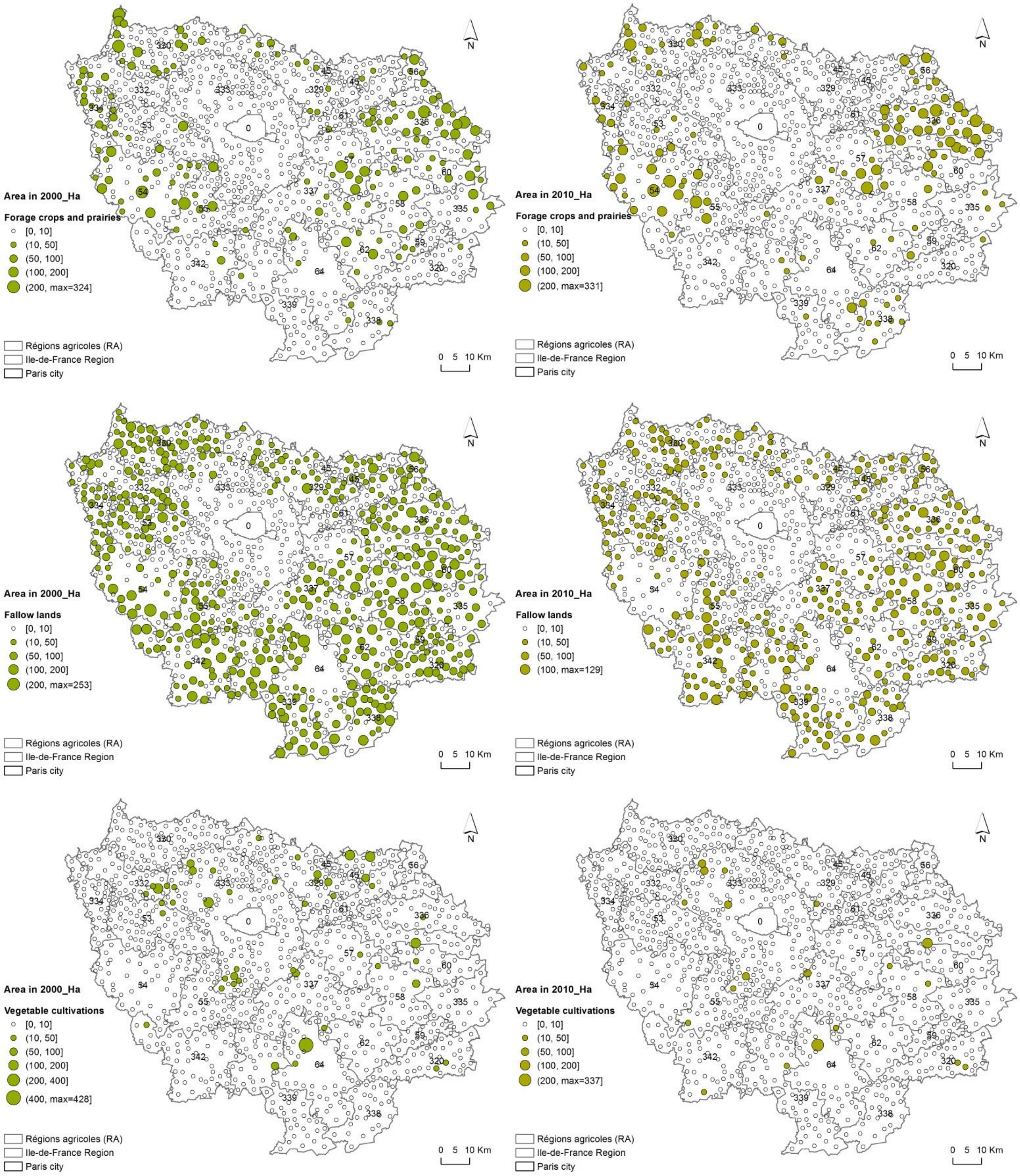
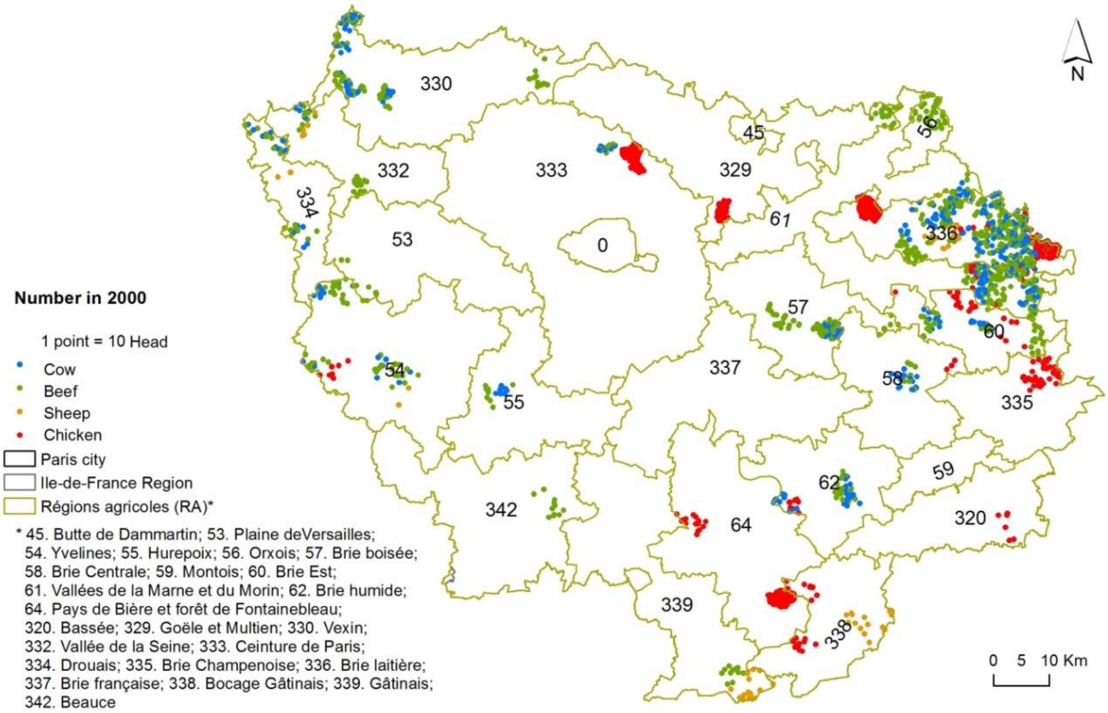


Fig. 2-6-2. Distribution of the principal agricultural lands in Ile-de-France in 2000 and 2010. Source: General Agricultural Census of 2000 and 2010, data at municipality level. Names of the "Régions Agricoles": see Fig. 2-6-1.



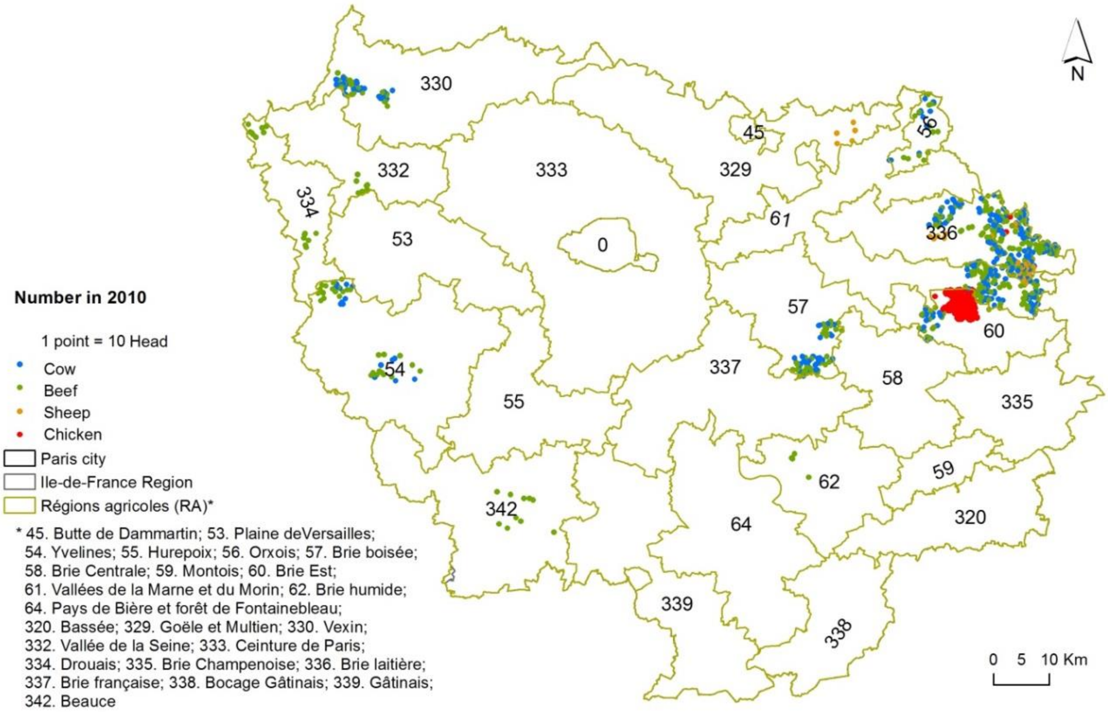


Fig. 2- 7. Distribution of the principal livestock in Ile-de-France in 2000 and 2010. Source: General Agricultural Census of 2000 and 2010, data at municipality level.

Important area of forage crops and meadows are located in the zone of Brie laitière, a traditional zone of livestock as revealed by its name. Two other zones also demonstrate distribution of forage crops and meadows: Yvelines and Drouais in the west and Vexin in the north-west. Accordingly, the remaining cattle and sheep, very marginal at the regional level, are raised in these zones. Farms specializing in COP crops and industrial crops increased while the mixed farming systems of crops and livestock decreased rapidly in the last century. That explains the drop of forage crops. According to the RGA of 2010, chickens, pigs, horses in Ile-de-France are raised in specialized farms, and the mixed farms of livestock and crops mainly concern cattle and sheep. 70% of the cattle in the region are raised in mixed crops-livestock systems and 26% are raised in systems specializing in livestock (Agreste, 2013b). 80% of the forage to feed these livestock comes from temporary and permanent meadows, 12% from corns and 8% from leguminous crops (Agreste, 2013b).

Vegetable cultivations scatter in the region, 44% of municipalities have at least one piece of land for vegetable cultivation, but only a dozen of municipalities have important area (Petit, 2013). As shown in Fig. 2-6-2, these municipalities are located in the immediate surrounding zone of Paris agglomeration, except for one at the side of Fontainebleau forest and several on the plateau of Brie. From 2000 to 2010, an important area for vegetable cultivation disappeared, especially in the Plaine de France in the north-east and the Plaine de Versailles in the west of the region. Besides systems specialising in vegetables, mixed systems are appearing that integrate open-field vegetable cultivation with COP crops and industrial crops (Agreste, 2013a).

The classification of agricultural holdings by type of farming in 2000 and 2010 (Table 2-3) confirms that there remain three principal production systems relying on arable lands: large-size open-field farms specializing in COP crops and industrial crops, mixed crops-livestock farming systems and fresh vegetable cultivations (including small fruits like strawberry). According to the above analysis, the regional spatial pattern of farming systems is quite homogeneous and dominated by the large size open-field crops. The mixed crops-livestock systems are maintained in particular zones where this type of farming forms the base of a territory identity. Fresh vegetable cultivations, unluckily, have largely regressed. They have lost their prosperity dating from 19th century in a belt surrounding the urban agglomeration (Poulot and Rouyres, 2000). This regional agricultural pattern does not correspond to the limits of the "Régions Agricoles". Comparing to 50 years ago, the actual agricultural pattern is much more simplified and trivialized.

Table 2- 3 **Classification of agricultural holdings by type of farming (OTEX[1]) in 2000 and 2010**

	Number of farms		Utilised agricultural lands (SAU, ha)	
	2000	**2010**	**2000**	**2010**
Large size open-field crops	4 542	3 881	536 151	528 164
Fresh vegetables and horticulture	684	340	6 042	4 346
Fruits and other permanent cultures	95	61	995	901
Viticulture	9	8	172	103
Cows	41	36	2 456	3 033
Beef	44	27	1 244	1 232
Mixed breeding of cows and beef	4	3	326	No data
Sheep and other herbivores	328	233	2 953	3 525
Off-soil breeding	95	55	2 024	947
Mixed farming of crops, livestock and others[2]	696	382	30 884	26 524

Source: General Agricultural Census of 2000 and 2010. [1]OTEX: Orientation technico-économique des exploitations. It's a European classification system of agricultural holdings that distinguishes their farming type by the dominant production(s) of the farm. [2]This category includes poly-cropping ("polyculture", e.g. mixed crops-fruits systems) and mixed crops-livestock systems ("polyculture-élevage").

Chapter 3

Integrated framework of MFA and ES for peri-urban agriculture and application in Ile-de-France Region

1. An integrated framework of MFA and ES for peri-urban agriculture

The general framework proposed in chapter 1 has explained the biophysical mechanism to develop a MFA system based upon maintenance of ecosystem services. This chapter further develops the framework by combining the demand side in the peri-urban context. Peri-urban farmers have direct contacts with a variety of stakeholders, e.g. urban dwellers, peri-urban residents and others. There are strong urban pressures grabbing lands. Farmers need to maintain the profitability of agricultural activities. Profitability is equivalent to productivity for most of the farmers. There are also growing demands for social and environmental benefits from agricultural lands, which can be constraints but also opportunities for peri-urban farmers. Furthermore, peri-urban area is under the control of more completed regulations and land use planning than rural area. The adapted framework of MFA and ES considers the particular social economic structure of peri-urban area and reveals the relations between ES and MFA (Fig. 3-1).

First, agricultural system includes the agro-ecosystem, the socio-economic system and their interactions. Agricultural functions rely on the benefits from agro-ecosystem, i.e. ecosystem services. Agro-ecosystem is surrounded by natural and semi-natural habitats. Farmers also manage some semi-natural habitats in their farm such as the field margins and hedgerow networks. Farmers, peri-urban residents, city dwellers, planners and policy makers are the main stakeholders in the socio-economic system. It may also concern regional or national authorities for the construction of public infrastructure such as airport, highway, prison and hospitals (Darly and Torre, 2013).

The adapted framework illustrates in a simplified way the flows of ES and disservices in and out of an agro-ecosystem, which have been more clearly described by the framework of Chapter 1. Regulating and supporting services sustain the three consumer-oriented services. Agro-ecosystem benefits from ES provided by surrounded natural and semi-natural habitats (e.g. pollination, biological pest control and water provision), and suffered from ecosystem disservices from the same source (e.g. pest damage and competition for water, sunlight, nutrients and pollination). Agro-ecosystem also participates in the maintenance of regulating ES (e.g. soil fertility and retention, resistance to natural disturbances and climate regulation), and supporting ES (e.g. nutrient recycling, biodiversity and wildlife habitats). The regulating services and supporting services benefit both agro-ecosystem and the surrounding natural and semi-natural ecosystems.

Among the three consumer-oriented services, the provisioning service of food, fiber and biofuel and the waste breakdown service necessitate farmers' conduit to benefit other stakeholders such as city dwellers and consumers in a distant market. The recreational, aesthetic and cultural services can be perceived directly by anyone approaching the peri-urban agricultural landscape. Farmers' interventions modify more or less agro-ecosystem and its relationships with surrounding habitats, and thus influence on the provision of ES.

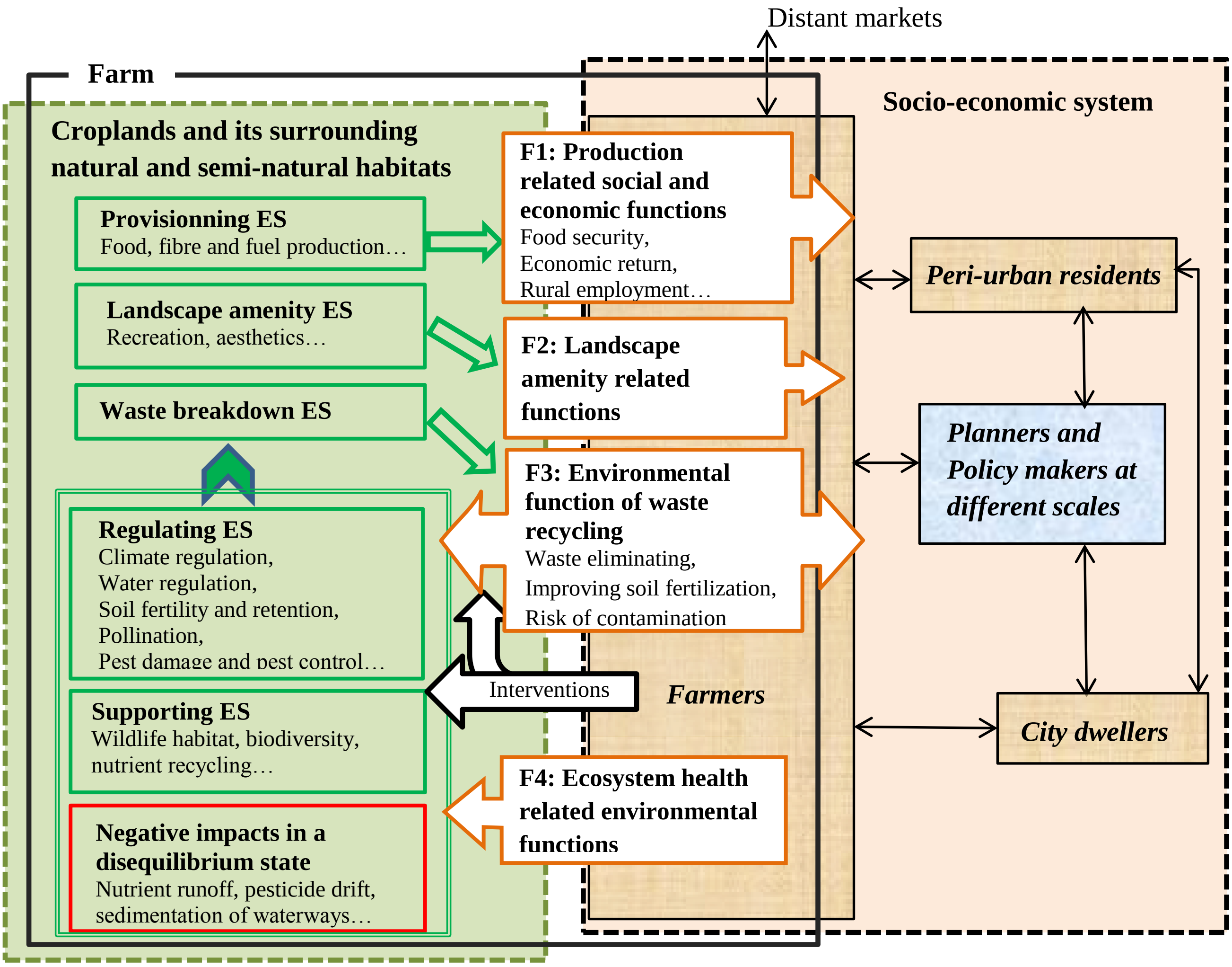


Fig. 3- 1. An integrated framework of multifunctionality and ecosystem services for peri-urban agriculture. F1, F2, F3 and F4: agricultural functions. ES: ecosystem services.

Accordingly, I distinguish four categories of agricultural functions, by comparing the list of functions in the literature of MFA (OECD, 2001; Boody et al., 2005; van Huylenbroeck et al., 2007; Zasada, 2011) with the underpinning ES.

The first category includes functions relying on the provisioning ES and determined by farmers' commercial strategies, such as food security, economic revenue and rural employment. The second category includes functions based upon landscape amenity ES, perceivable by anyone approaching or working in peri-urban agriculture, such as recreational, aesthetic and cultural services. Farmers can strengthen or limit these functions for example by working on agro-tourism or putting up fences. Farmers are usually themselves beneficiaries of these services, and enjoy the lifestyle. The third category includes the function of urban waste recycling which is related to two ES, namely, the waste breakdown ES and the fertilization ES. It may also concern the risk of contamination to soil and water. Finally, the fourth category includes a variety of environmental functions that maintain a healthy state of agro-ecosystem and the surrounding natural habitats. These are “environmental services” from farmers, as claimed by Lugo (2008) and Aznar et al. (2009). Farmers’ environmentally oriented practices contribute to the maintenance of regulating ES and supporting ES, and the reduction of negative impacts from conventional agriculture, such as nitrogen leaching, pesticide drift, soil erosion and consequent sedimentation in waterways.

The framework facilitates examination of the important questions around peri-urban agriculture (Box. 1). Preservation of peri-urban agriculture does not only depend on a healthy ecosystem to deliver ES, but also depends on the social economic system to stand against urbanization and land abandonment. Especially, instruments should relink peri-urban agriculture with urban population, because as in the French case, the number of peri-urban farmers is quite marginal comparing to other residents. When food production disconnects with local food supply, other actors in the local territory can hardly appreciate the production service of peri-urban agriculture. It is similar for other ES and functions of peri-urban agriculture.

Box 3-1. Important questions around peri-urban agriculture

(1). How to halter the disconnection between food production and food security function?

(2). How does peri-urban agriculture coordinate urban demands for land, food and environmental services?

(3). Do different production systems react differently toward urban pressures?

(4). How does the evolution of policies reveal the changing public awareness to specific functions and ecosystem services?

(5). How does the use or improvement of one function act on the delivering of other functions?

(6). How to understand and regulate the roles of farmers in modifying and affecting agro-ecosystem in order to reach a win-win situation for all the stakeholders in the system?

(7). Modern farming has growing dependence on human inputs due to ignorance and degradation of the ecosystem services from agro-ecosystem. How can it be possible to promote ecosystem services rather than to use pesticide, irrigation, and mineral fertilizer for maintaining the equilibrium of agro-ecosystem?

Land use changes are the consequence of the interactions among multiple functions and related stakeholders. Farmers mainly care about rural employment and economic revenue by selling foods and materials to the markets. Peri-urban residents and urban dwellers are interested in local food, recreational and aesthetic services from agricultural landscape. New hobby farmers from the city usually have less interest in food production but more in recreational and aesthetic services. Land use planners and policy makers coordinate all of these concerns at a higher level. They can also emphasize on specific functions being weakly noticed, e.g. biodiversity conservation and other environmental functions. The change of social demands for particular agricultural functions would promote the development or disappearance of particular types of farmlands. Market and policy instruments may help to express the value of a specific function and thus influence on agricultural transition and land use change. For example, labelling of local food or organic food in the food market makes it possible to compensate the environmental value associated with the specific agricultural practices (Paül and McKenzie, 2013).

Based upon this conceptual framework, the following subsections analyze the evolution of MFA/ES from peri-urban agriculture in Ile-de-France.

2. Application of the framework in Ile-de-France Region

Multiple materials were used to investigate the change of ES and MFA associated with the evolution of agricultural lands: existing literature in English and in French on the topic, annual agricultural statistics (SAA) and the general agricultural census (RGA), documentary materials and urban planning regulations of the region, other statistics and materials. The present study is not a quantitative valuation of MFA and ES. Instead, it uses the abundant qualitative and quantitative information from different sources to understand the interactions between land use changes and the evolution of MFA and ES around peri-urban agriculture. Similar to Chapter 2, the statistical data across such a long period probably have varying accuracy. It was the trends rather than the exact numbers, which led to the formulating of the conclusions.

2.1. Food production ES and related social and economic functions

Food production is the primary ES produced by peri-urban agriculture. Ile-de-France region was among the first regions that promoted agricultural modernization and has efficiently improved productivity.

Taking wheat, the primary crop accounting for more than 50% of arable lands, as an example, its five-year average yield (Fig. 3-2) increased rapidly from 2.335t/ha in the period of 1946-1950 to 8.127 t/ha during 1996-2000, and stayed relatively stable thereafter. Productivity of potatoes increased from 14.7 t/ha in 1906 to 48.7 t/ha in 2014. The regional wheat yield was around 1t/ha higher than the national level of France. Other principal crops also had higher yields than the national level (DRIAAF, 2010). As for vegetable cultivation, an intensive way trying to have more times of harvest in a year since the 19^{th} century (Phlipponneau, 1956) remarkably increased productivity per hectare. According to SAA, Ile-de-France cultivated 44 species of fresh vegetables with an average yield of 20.5 t/ha in 2014. The average yield of four species under green house (strawberry, cucumber, melon, tomato) was 86.1 t/ha, five times the yield of the same four species cultivated in open air (16.9 t/ha). The yield of fruits (including hazelnut and chestnut) was 16.4 t/ha in 2014, twice of the yield in 1906 of 7.3 t/ha.

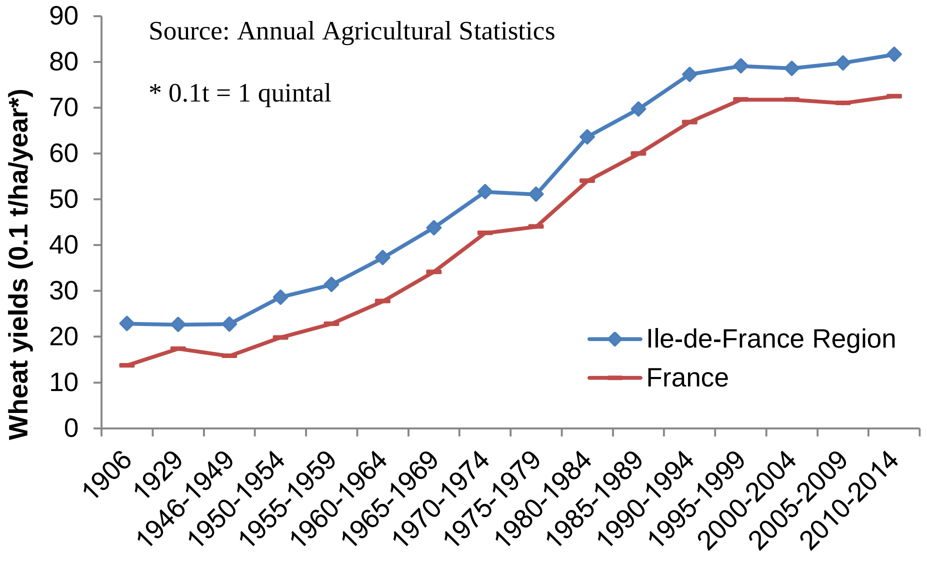


Fig. 3- 2. Trend of the five-year average yield of wheat in Ile-de-France Region

The provisioning ES concerns three functions: food supply, economic revenue and employment.

2.1.1. Food supply function

(1). Cereal, oilseeds and protein crops

Despite the increasing productivity, the function of supplying food to people living in the region has become more and more marginalized. The production of wheat, barley, corn, rape and dried peas increased rapidly in the 20th century, combining the effects of productivity improvement and area expansion. Remarkably, the region produced 2 million tons of wheat in 2014. Whereas according to a report of CREDOC, the Research Center for the Study and Observation of Living Conditions (Toullalan, 2012), 90% of the regional wheat production was delivered out of the Ile-de-France Region. The wheat harvested in the region could produce 5 times that of the flour consumed in the region, but 45% of the regional consumption relied on importation (about 135 660 t wheat flour).

(2). Fruits and vegetables

Table 3-1 compares the consumption and production of fruits and vegetables in Ile-de-France in 1906, 1946 and 2014. According to the SAA of 1906, 6251 t fruits and 5232 t vegetables were delivered by railway from out of the region to Les Halles, "the Belly of Paris". The regional production of fruits was 47 703 in the same year. For the regional production of vegetables, the SAA of 1906 only noted the production from the open-field systems (2427 t fresh vegetables) and did not record the production from the enclosed vegetable gardens, the "maraîchage" systems. However, the number is available for the year of 1950 (25600 t) in the study of Phlipponneau (1956). As the area of "maraîchage" in 1950 (11 800 ha) was quite close to that in 1906 (11 539 ha) and the technique did not change too much during that period (Philpponneau, 1956), it can be assumed that the production from "maraîchage" systems in 1906 was quite close to the level of 1950. Supposing that vegetables and fruits produced in Ile-de-France, the capital region, were principally consumed within the region, the sum of the importation and the production gave an estimation of the regional consumption. Therefore, the self-sufficiency of fruits and vegetables in 1906 were both higher than 80%.

Table 3- 1 Production and consumption of fruits and vegetables in the region of Ile-de-France

		In 1906	In 1946	In 2014
Population (person)		4 960 529[1]	6 597 930[1]	12 005 077[1]
Fruits	Production (t)	47 703[2]	16 855[4]	11 956[5]
	Consumption (t)	54 231[3]	No data	425 000[6]
	Ratio of production/consumption	88%	-	2.8%
Vegetables (t)	Production (t)	28 027[3]	206 847[3]	85 863[5]
	Consumption (t)	33 259[3]	No data	480 000[6]
	Ratio of production/consumption	84.3%	-	17.9%

Sources: [1]INSEE; [2]Annual agricultural statistics of 1906; [3]estimation based upon the data from annual agricultural statistics and Phlipponneau, 1956; [4]Annual agricultural statistics of 1946; [5]Annual agricultural statistics of 2014; [6]Toullalan, 2012

In 2014, combining decreasing area and increasing productivity, the production of fruits remained 11 956 t, as ¼ of the level in 1906, but the regional production was only 2.8% of the regional consumption, far less than the level in 1906. The regional production of vegetables was 85 863 t in 2014, and equaled 17.9% of the regional consumption, which was estimated as 480 000 t (Toullalan, 2012). The self-sufficiency of vegetables thus has decreased a lot but remains much higher than fruits.

The year 1946 was the first year of reconstruction after the Second World War. It was special because the war had destroyed the transportation system and local food supply became very important. As shown in Table 3-1, fruits production was only 35% of the level in 1906, but vegetable production was able to increase substantially. The open-field vegetable cultivation had a historical area of 14 157 ha and produced 181 247 t fresh vegetables. Because the area of "maraîchage" systems is also quite close to that of 1950, the production of 1950 (Philpponneau, 1956) was used as estimation for the year 1946. Thus the total amount of fresh vegetables produced in 1946 reached 206 847 t, about 2.4 times of the production in 2014.

Today, the average consumption of fruits and vegetables of one person has increased a lot comparing to one hundred years ago. Whereas, the average consumption of 110 g vegetables and 97g fruits 1 person one day is not enough comparing to the recommendation of World Health Organization, which requires at least 500 g vegetables and fruits one day for a healthy diet. The population in Ile-de-France region began to reduce the consumption of fresh vegetables when both men and women went to work and they had little time for cooking (Régnier et al., 2006). Ile-de-France region keeps an extraordinary production of lettuce accounting for 26.9% of the area for vegetable cultivation. One reason should be that lettuce saves the time for cooking. However, a study on Ile-de-France Region showed that people with higher income consumed more vegetables and fruits (Toullalan, 2012). Vegetables destined to fresh markets declined less than that destined to transformed products in Ile-de-France (Agreste, 2013a). The supplying of fresh vegetables and fruits will be more important in the future.

(3). Animal products

Livestock became the less important according to the annual agricultural statistics. In 2014, the region had 28 392 cattle, 10 859 sheep, 2 108 goats and 7444 pigs. Comparing to in1906, the region lost 86.1% of cattle, 98.6% of sheep, 75% of goats and 73.6% of pigs.

In 1906, animal raised in Ile-de-France supplied 7009.8 t meat to Paris through the market of Villette and Les Halles, accounting for 3.55% of the consumption in Paris. Meat imported by rail way accounted for 25.8%. 74.2% of red meat and 88% of pork came from the slaughterhouse in Paris, so the periphery area of Paris provided a service to raise the animal for a short period. Forage crops from peri-urban area were sold here for this purpose. Today, local provisioning of meat is marginal and indirect (Toullalan, 2012): the regional consumption of meat was 180 000 t in 2010, among which, 47.2% was provided by the Rungis International Market, the substitute of Les Halles in the southern suburbs from 1969. There remain only five slaughterhouses (all "Halal") in the region, which provided 5 035 t meat in 2010, accounting for 2.8% of the consumption. Half of the regional needs was met by the slaughterhouses in nearby regions.

At the end of 19th century, the fresh milk produced by 2000 producers met 2/5 of the regional consumption (Phlipponneau, 1949), but today only 107 producers exist (Toullalan, 2012). They produce about 46 400 000 liters of milk a year, equivalent to less than 1/19 of the regional consumption. The proportion of local supply is even less when half of the production goes to industries out of Ile-de-France Region.

The AMAP (Associations for the Preservation of Peasant Agriculture), have developed quickly in the Ile-de-France since 2003 as the French style Community Supported Agriculture. The number of associations reached 280 at the end of 2011, concerning almost 15 000 families and 180 farmers (Aubry et al., 2008; Poulot, 2014). These numbers account only a small proportion of the regional population, but these associations have important educational and demonstrative value. Hopefully, they will contribute to the enhancement of local food supply function in the region.

2.1.2. Function of economic revenue and employment

The function of supplying economic revenue to farmers is usually the direct and important motivation in driving farmers' choice of strategies. Table 3-2 presents the principal information about the economic revenue and employment and Table 3-3 compares the average production value of different agricultural land uses, based upon the Departmental Economic Account for Agriculture in France from 1970s.

Table 3- 2 Evolution of economic revenue and employment from 1970 to 2010 in Ile-de-France Region

	In 1970	**In 1980**	**In 1990**	**In 2000**	**In 2010**
Number of farms	14 056	11559	8 962	6 474	5 198
Number of labors from the family of farm owners (UTANS[1])	19 684	16718	10 888	6 908	5 160
Number of workers (UTAS[2])	13 967	No data	8 042	6 250	5 082
UTANS[1]/farm	1.40	1.45	1.21	1.07	0.99
UTAS[2]/farm	0.99	No data	0.90	0.97	0.98
Average utilized area of a farm[3] (ha)	45.62	53.08	66.03	90.09	109.72
Average gross value added of a farm[4] (euros)	118 065	108610	105541	110339	117865
Average gross value added per hectare[4] (euros/ha)	2588	2046	1598	1225	1074
Average subsidies[4,5] to a farm (euros)	3 189	2299	559	3 202	37 539
Salary of a worker[4] (euros)	15 954	No data	19 068	20 063	27 040
Gross revenue per UTANS[1, 4,6] (euros)	67 535	42 847	56 597	68 153	105 798
Gross revenue per hectare[4] (euros/ha)	2 072	1 170	1 037	809	954

Sources: Departmental Economic Accounts for Agriculture in France. [1]UTANS: Unités de travail annuel non salaries, Annual Work Unit from the family of the farm owner. Annual Work Unit represents the labour provided by one person in full-time employment on an agricultural holding. [2]UTAS: Unites de travail annuel salariées, Annual Work Unit employed by the farm owner. [3]Utilised Agricultural Lands (SAU). [4]Equivalent to money in 2010. [5]Not including subsidies on the price of products. [6]Fixed-capital consumption has not been subtracted.

Table 3- 3 Evolution of production value and subsidies of different agricultural land use

	Production value[1] (euros/ha)			**Subsidies on products[1] (euros/ha)**		
	In 1990	**In 2000**	**In 2010**	**In 1990**	**In 2000**	**In 2010**
Cereal crops	1 738	1 017	1 392	0	411	0
Oilseed crops	1 414	632	985	0	542	0
Protein crops	1 589	681	988	0	516	143
Industrial sugar beets	2 594	3 430	2 524	0	0	0
Forage crops	2 400	1 873	1 415	0	64	0
Fresh vegetables	22 868	22 449	38 898	0	0	0
Flowers	347 119	332 354	159 120	0	0	0
Potatoes	6 204	7 665	14 597	0	190	132
Fruits	18 430	18 116	26 390	0	0	0

Sources: Departmental Economic Accounts for Agriculture in France. [1]Equivalent to money in 2010.

(1). Economic revenue

Overall, lands are cultivated by less people in order to maintain the profitability of agricultural activities. Results showed that the average economic revenue of a farm owner decreased 36.6% from 1970 to 1980, and then kept on increasing thereafter. It reached 105 798 euros a year in 2010, about 2.5 times of the level in 1980, with inflation considered. However, the number of farm owners remarkably and persistently decreased in this period, from 19 684 in 1970 to 5 160 in 2010. Thus, the total amount of economic revenue from agriculture was decreasing in the region. In fact, the average gross value added per hectare decreased persistently from 2588 euro/ha in 1970 to 1074 euro/ha in 2010. In 1970s, the family of farm owner offered 1.4 units of labor in a farm, but less than 1 in 2010. Meanwhile the average size of a farm was becoming larger, from 45.62 ha in 1970 to 109.72 ha in 2010.

Different agricultural systems have different performances and destinies. As shown in chapter 2, the “Grande Culture” systems composed by COP crops and industrial crops have dominated agricultural pattern in the region, the specialty crops like fresh vegetables and fruits became marginal. According to Table 3-3, COP crops had decreasing average production value per hectare and were much lower than that of vegetables, flowers and fruits. The cost would not increase too much by using motorized agricultural technics, so the farmers of “Grande Culture”, especially of COP crops, had a strong motivation to enlarge their farm size. Vegetables and fruits, to the contrary, had increasing average production value per hectare, but they are more labor demanding. The cost increased rapidly with farming size because motorization is more difficult and the commercial chains are more complicated, comparing to COP crops. Although the production value per hectare of fresh vegetable cultivation is 28 times that of cereal crops, the difference regarding economic revenue of a farm is not that much. A vegetable cultivation of 10 hectares needs at least three full-time labors from the family or salaried workers; while a cereal farm of 100 ha can be maintained by the farm owner himself. Vegetable cultivation has more constraints than cereal crops, such as difficulties in finding qualified workers, higher land rents when located close to urban areas, and unstable commercial conditions.

Subsidies have important role in adjusting the economic revenue of farmers. They include two parts: subsidies on products in the form of base price and direct subsidies to farmers. The reform of Common Agriculture Policies (CAP) of European Union in 1992 gradually decoupled the subsidies from products, and turned to direct payments to farmers for concerns of rural development and environmental protection. In 2000, farmers in the region received in total 207.2 million subsidies in the form of base price and 20.7 million as direct payments (equivalent money in 2010), while in 2010, 7.81 million in the form of base price and 195.13 million as direct payments. Subsidies become more important in farmers' revenue. In 2010, the average direct subsidies accounted for 35% of the gross revenue of the farm. However, subsidies are principally given to promote COP crops and rarely to fresh vegetable cultivations.

Therefore, the increasing of productivity does not necessarily improve economic revenue. Even the extraordinarily good harvest of cereal crops in 2009 did not compensate farmers' lost caused by a fall in price (Agreste, 2010). Specialty crops (vegetable, fruits and horticulture) accounted for only 1% of the regional SAU but brought 15% of gross profit. Specialty crops are highly interesting in improving the profitability of lands. This is especially interesting knowing that products related subsidies for COP crops largely disappeared in 2010.

(2). Employment

As for the function of employment, the numbers of farm owners and workers have persistently decreased with the number of farms. As shown in Table 3-2, the remaining 5198 farms in 2010 were equivalent to 40% of the number in 1970, and the total number of labors remained only 30.4%. The number of labors from the family of farm owners decreased even faster than the number of workers. The former lost 73.8% while the latter lost 63.6%. The average number of workers in a farm was always less than 1and even slightly increased during the last thirty years. This is possibly a result of the decrease of farm numbers or the enlargement of farm size.

The annual salary of a worker kept on growing, from 15 954 euros in 1970s (equivalent to money in 2010) to 27 040 euros in 2010. It was about ¼ of the farm owners' revenue in 2010. The system of "Grande Culture" has succeeded in replacing human labors with motorized machines. Whereas, the more labor demanding vegetable and fruits cultivations have difficulties in employing workers, because of the expensive cost on one hand, and lack of professional ones on the other (Charvet, 2003). Furthermore, agricultural employment opportunities are less attractive because the work is physically too hard.

New installations of young farmers are critical to improve the function of employment of peri-urban agriculture, but the number decreases since 1990 because of a variety of reasons: difficulties in obtaining land, start-up capital, and precarious lease contract, and others (DRIAAF, 2010).

2.2. Alternative functions and related ES

Population in Ile-de-France region are becoming more aware of the alternative functions, i.e. recycling of urban waste, the recreational, aesthetic and cultural functions linked to landscape amenity, and environmental functions for protecting the delivering of ES. This section analyzes the evolution of these functions and related ES, and investigates how to integrate concerns on these functions and ES into the conventional strategy dominated by economic and social functions linked to food production.

2.2.1. Landscape aesthetic and cultural ES and related functions

Peri-agriculture has important recreational, aesthetic and cultural functions originated from human interactions with landscape aesthetic and cultural ES. There are two levels of interactions. The first are simple or temporary activities, such as watching and walking through agricultural fields, or visiting a farm in the weekends. The second level includes longer or repetitive participations in agricultural activities, such as working on peri-urban agriculture as a lifestyle, or as a territory identity.

(1). Peri-urban agriculture as a landscape

The impressionist painters were the first who were attracted by the open-field agricultural scenery on the plateaus (DRIAF and IAURIF, 2004). The growing peri-urban residents followed them in search of open space and natural environment from 1960s. The process of peri-urbanization, commonly seen in France and other European countries, brought to peri-urban areas a complicated composition of residents (Mathieu, 1990; Prost, 1991; Berger and Saint-Gérand, 1993). A national level study of CREDOC in France in 2001 showed that only 8% of the peri-urban residents had negative perceptions towards rural area (Perrier-Cornet, 2002). “Quiet”, “purity”, “nature”, “freedom” were the expressions mostly used by people. However, only 10% of the people investigated thought of agriculture as the first image of rural area.

The peri-urban residents in the “without-roots group”, as distinguished by Guisepelli (2005) in a study of the alpine corridor, are especially not interested in agriculture but greenery and forests. Guisepelli (2005) also distinguished two other groups of residents: one nostalgic group appreciating traditional agricultural practices and landscapes and one group of new residents with strong ecological awareness. Actors in the two groups cooperate and actively support the local development of traditional or organic agriculture. Nevertheless, they also have conflicts with farmers of large-scale mechanized farming.

In Ile-de-France Region, new peri-urban residents demand to restore the landscape damaged by urbanization and modern agricultural technics for the improvement of living conditions (Poulot and Rouyres, 2000, 2007). The governors of Ile-de-France Region initiated several times of reparcelling (“remenbrement”) after the Wars in order to promote agricultural modernization. Reparcelling was generally the concentration of land parcels to favor mechanization. This has fundamentally changed the agricultural landscape in Ile-de-France. The size of farmlands has gone beyond 80 or 100 ha. Rural ways, hedgerows, small woods have been cleared up. The huge size of agricultural fields makes it difficult to entre for hiking. Simplified landscape structure has also damaged landscape variety. However, the open, vast, and free fields become a symbol of the region (Charvet and Poulot, 2006). In a photo competition organized by IAURIF in 2008 on agriculture in the region, a great number of photos were of the open, vast fields of “Grande Culture”. The open-fields of “Grande Culture” still have positive images in the sense of aesthetics.

(2). Peri-urban agriculture as an activity for weekend

Besides peri-urban residents, it becomes also popular for citizens to pass their weekends in the peri-urban agricultural area (Poulot, 2010). About 135 farms have registered in the database of the Chamber of Agriculture of Ile-de-France reporting that they are offering a variety of recreational activities for citizens. The actual number of such farms should be more than that. These activities include restaurants, hotels, camping, equestrian gite, fishing, farm visiting and fruits or vegetables piking. Fig. 3-3 shows that these farms are principally located in the outer suburbs where important agricultural lands remain. The western part of the region has more this kind of farms than the eastern part. Their spatial patter presents important relations with the Regional Natural Parks (PNR). Four concentrate zones can be distinguished: the PNR of Vexin, the part of Yvelines between Seine and the forest of Rambouillet, the eastern part of PNR of Haute-Vallée-de-chevreuse, and the western part of PNR Gâtinais-Français in the department of Essonne. Three of these zones are located in or immediately outside the PNR. The municipality of Etampe even has three farms offering farm visiting and hotel.

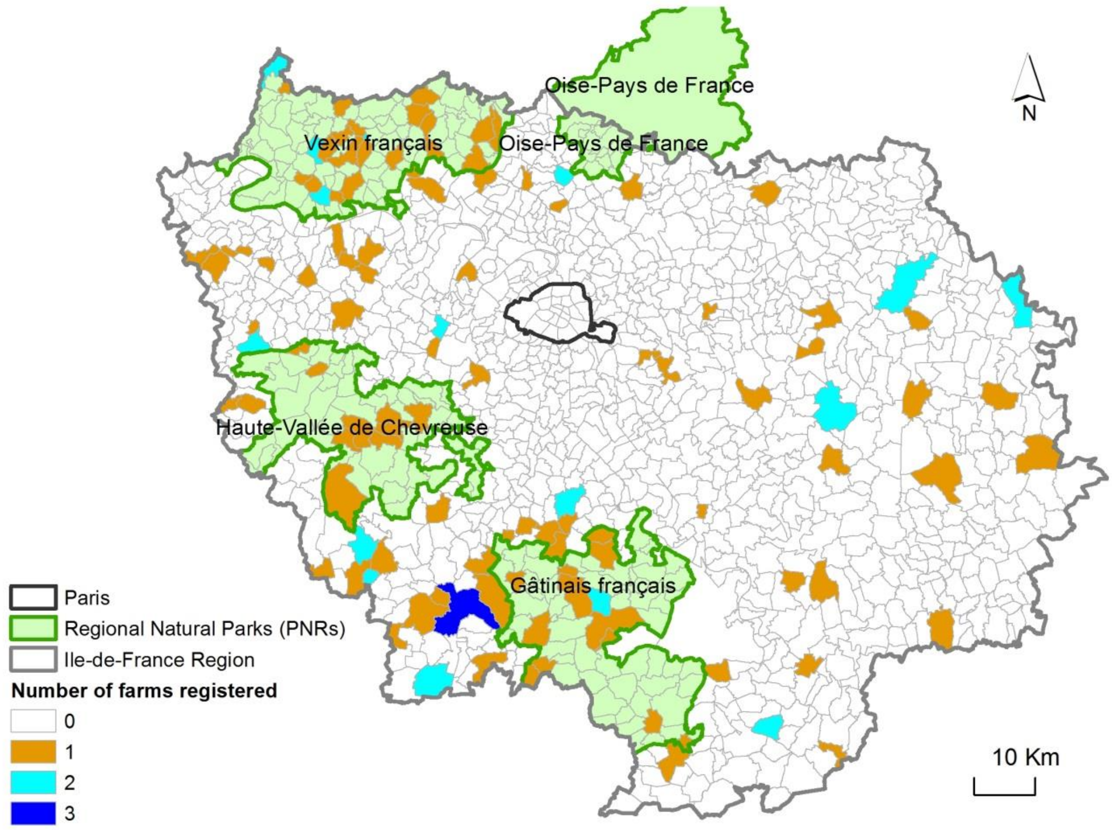


Fig. 3- 3. Number of farms engaged in agri-recreational activities in each municipality of Ile-de-France. Source: the Chamber of Agriculture of Ile-de-France

(3). Peri-urban agriculture as a lifestyle

Agriculture is also a lifestyle beyond the scenery beauty. Based upon in-depth interviews in Ile-de-France Region, Brédif and Pupin (2012) claimed that farmers chose to stay in peri-urban areas because they felt having their roots there after having established for several generations. Many actors did not support the idea to change agricultural spaces into gulf, forest or urban parks to conserve open space against urban construction. Another example is that a senior manager in a financial company decided to be a professional farmer, working on organic farming on the plateau of Saclay.

Hobby farming is also a way of engagement in agriculture as a lifestyle. In Ile-de-France Region, it includes first the allotment gardens. “Workers gardens (jardins ouvriers)” appeared at the end of 19th century for being cultivated by the workers of big factories; they changed to “family gardens (jardins familieux)” after the Second World War (Dubost, 2007). The main role of family gardens changed from food supply to recreation. The number of family gardens declined in the rapid urbanization during 1960s and 1970s, and then gained back importance from the 1980s, especially in the zone of sub-centers, in front of the collective residences and in the interstitial spaces among the built-up lands

(Cabedoce, 2007). Nowadays in Ile-de-France, new forms of collective gardens are emerging in response to the demands of multifunctionality, and food supply becomes important again (Pourias, 2014). Private gardens used to be an important form of hobby farming. Phlipponeau (1956) documented that the distribution of private gardens were closely linked to the location of individual houses in the valleys and on the slopes in the peri-urban area. The house owners cultivated a variety of fruits and vegetables in their gardens for self-consumption and for a lifestyle. Private gardens today are less used for agricultural activities.

(4). Peri-urban agriculture as a territory identity

Agriculture becomes a territory identity when different actors in an area cooperate to improve the development of a local agriculture. In Ile-de-France Region, 58% of the farms are not managed by land owners, accounting for 84% of the SAU, according to the RGA of 2010. However, the farmers usually cultivate the same lands since several generations, and the lease contract can be inherited or divided among his sons and daughters (Barthez et al., 1988). Therefore, the agricultural identity in Ile-de-France is a combination of heritage and invention depending on the interactions among actors (Poulot, 2010).

Many associations and organizations are active in mobilizing the communication of different actors in a geographical area, for building a territory identity that links agriculture with the residents. The Regional National Parks (PNR) and the Agri-Urban Projects are among the most important initiatives. The PNRs are created for preserving natural and cultural landscapes and heritages against the invasion of major infrastructure and urbanization (Allie and Bryant, 2003). They try to establish a common memory of the Park through different measures, e.g. museums on local agricultural traditions, festivals for visiting the farms or discovering local products, and others (Poulot, 2010). The ten Agri-Urban Projects in Ile-de-France are more for the objective to integrate a local and sustainable agriculture in urban management, which responds to the local demands of new residents (Poulot, 2008). They concern either "Grande Culture" (Saclay, Versailles…) or specialty crops (Cergy, Vernouillet, Triangle Vert…) or both.

2.2.2. Function of urban waste recycling and related ES

Urban waste recycling in agriculture is a special function of peri-urban agriculture. It benefits the urban population in eliminating urban waste and the farmers in providing organic fertilizers or soil improvers. The underpinning ES include waste break down, fertilization and improvement of soil structure. Waste break down service normally combines with the service of fertilization, because urban wastes are used in agriculture only when they have interesting agronomic effects.

(1). Agricultural use of urban wastes in Ile-de-France

Table 3-4 concludes the quantities of waste produced in Ile-de-France and the part used in agriculture, according to the Regional Plan for Elimination of Household and Similar Wastes (PREDMA, 2009). Urban originated wastes used in agriculture mainly include sewage sludge, sewage sludge compost, green waste compost, bio-waste compost, household waste compost.

Agricultural uses of sewage sludge from wastewater treatment plants include land application and composting. The five plants of SIAAP (Syndicat Interdépartemental pour l'Assainissement de l'Agglomération Parisienne) manage the sanitation service for the Paris agglomeration (including Paris city, the three departments in near suburbs and some municipalities in the outer suburbs). They produced 146 300 t (dry matter, DM) sewage sludge in 2007, accounting for 75% of the total amount produced in Ile-de-France. Then, 57% were used in agriculture, 26% incinerated and 17% sent to land filling. Only 10 000 t (DM) are spread inside the region, i.e. in the department of Seine-et-Marne, Val-d'Oise and Yvelines, representing 12% of agricultural uses of SIAAP. In the outer suburbs outside the limit of SIAAP, there are more than 400 plants managed by intermunicipal sanitation syndicates or individual municipalities. They produced 47 400 t (DM) sewage sludge in 2006, and disposed of 72% in agriculture use, 11% to incineration, and 17% to landfilling. Comparing to SIAAP, these plants rely more on agricultural lands inside the region for disposal of their sludge.

Table 3- 4 Quantities of wastes produced in Ile-de-France and used in agriculture

	Quantity collected	Disposal strategies	Agricultural use
Sewage sludge			
SIAAP[1]	146 300 t DM[3]	57% was used in agriculture, 26% incinerated and 17% to landfilling	72 800 t DM was sent to composting plants or spread on farmlands outside Ile-de-France, 10 000 t DM was spread inside the region
Outer suburbs[2]	47 400 t DM[3]	72% in agriculture, 11% incinerated and 17% to landfilling	34 000 t DM was sent to composting and spreading mainly inside the region
Green waste[4]	270 000 t	All in composting	138 873 t compost was produced and all used in agriculture
Bio-waste[4, 5]	31 596 t	60% in composting and 40% in methanation,	4 789 t compost was produced and used in agriculture
Solid household[4] **waste**	3 903 000 t	88% incinerated, 6.34% to landfilling, 4.4% in composting and 1.2% in methanation	75 264 t compost was produced and used in agriculture

Source: PREDMA, 2009. [1]SIAAP (Syndicat Interdépartemental pour l'Assainissement de l'Agglomération Parisienne), data in 2007 were used because a new station Seine Grésillons was opened in 2006 and there was a pollution incident of PCB (polychlorinated biphenyls) in 2005. [2]Outer suburbs: the rest part of the Ile-de-France Region outside the limit of SIAAP, data in 2006. [3]DM: dry matter. Sewage sludge has increasing percentage of dry matter after mechanical dewatering, thermally drying, and composting process. See table 3-5 for detailed numbers. [4]Data in 2005. [5]Separate collection of bio-waste was only adopted partly by three intermunicipal sanitation syndicates: the SMETOM de Provins (77), the CA de Cergy-Pontoise (95), and the SIVOM de la Vallée de l'Yerres et des Sénart (91).

Green waste is almost totally processed in composting. In 2005, Ile-de-France collected 270 000 t green waste through two ways: waste collection center or door-to-door collection in the zone of individual houses mainly located in the outer suburbs. The composting platforms produced 138 873 t compost and used all in agricultural lands inside Ile-de-France, concerning 5.8% of the regional SAU (Utilized Agricultural Lands). The separate collection of Bio-waste, the biodegradable waste from kitchen, is still marginal in the region. In 2005, among the 31 596 t bio-waste collected, 60% was delivered to composting and 40% to methanation. The 4789 t compost produced also went to agricultural lands in Ile-de-France. Household waste is the most important part of solid wastes collected by public service in the region. In 2005, the region collected 3903 000 t household waste, and only processed 4.4% in composting and 1.2% in methanation. These processes resulted in 75 264 t compost for agricultural use.

(2). Agronomic effects of urban waste use

Dhaouadi (2014) summarized in his dissertation the multiple agronomic effects of different organic wastes based upon a great number of references. Table 3-5 is a brief synthesis based upon his review.

Table 3- 5 Agronomic characteristics of different urban wastes documented in the literature[1, 2]

	DM % RM	OM % DM	N_t % DM	N_m % Nt	P_2O_5 % DM	K_2O % DM	C/N	N_{sh} % Nt	Fertilizer value of P_{sh} equivalent to a reference (%)	$\Delta C_i/C_{cum}$	g NH_3 volatilized /kg Nt
Sewage sludge											
Liquid	3	70	6.7~13.3	10~20	6.7~10	3	4~5	45	-	0.3±0.15	-
Dewatered	15~22 or 18~25	50	3~5.5 or 1.5~3	<5	3.3~5	0.4	5~10		-		-
Dewatered and limed	25, 27 or 35	30 or 46	2.7, 3.3, or 2.4~3.6	7 or <10	3.5 or 2.4~4	0.3 or 0.4	6, 9.7, or 8~11	40	88±5		160~175
Thermally dried	>90, or 95	55	3.5~6 or 4.5	2 or 10~15	-	-	6.1, or 6~7.5	35	71±20		83~166
Compost											
Sewage sludge	47 or 65	52 or 54	1.5 or 2.3	1.6 or 20	1.6 or 3.4	0.8 or 0.9	11.3 or 18	8, <20 or 26	73±18	0.37±0.05	20
Green waste	50 or 59	45 or 46	0.8~1.5	7	0.4 or 0.6	0.7 or 1.4	15~15.3	9	54	-	20
Bio-waste	62	46	2.2	8	1.3	1.8	11.4	8 or 10	-	0.37±0.13	8
Household waste	65	57	1.7	10	0.8	1.0	18.4	10~20	54		7

Source: summarization of Dhaouadi (2014) based upon a number of references. [1]Explications to the index: DM: dry matter. RM: raw material. OM: organic matter. N_t: total nitrogen. N_m: mineral nitrogen. C/N: carbon-nitrogen ratio. P_2O_5: total phosphorous. K_2O: total potassium. N_{sh}: nitrogen available in short term (mineral nitrogen + mineralized). Fertilizer value of P_{sh} (%): a coefficient of equivalence for phytoavailability in short term of phosphorous brought by urban waste use comparing to a reference e.g. superphosphate or ammonium phosphate (Morel et al., 2003). $\Delta C_i/C_{cum}$: effects of i years of urban waste use in increasing carbon accumulation in the soil, comparing to a control field without urban waste use. [2]Number varies in different references for some index; see Dhaouadi, 2014 for these references.

Abbott and Murphy (2007) defined soil fertility as including three major components: chemical, physical and biological fertility. Use of sewage sludge and urban wastes compost benefit all the three aspects (see review of Dhaouadi, 2014). They introduce nutritional elements N, P, K in mineral form and organic form to soil. Sewage sludge provides a higher proportion of nitrogen available for plants in the first year. Mineral nitrogen plus organic nitrogen mineralized in the first year arrives up to 45% of total nitrogen in sewage sludge. Composting process stabilizes nitrogen in organic form, and makes it more difficult for mineralization in the short term. Thus, all kinds of composts are more interesting in providing organic matter and long-term fertility. Similarly, for the short-term availability of phosphorous, limed sewage sludge has a value equivalent to 88% of mineral phosphorous fertilizer, dried sewage sludge and compost of sewage sludge around 70%, while green waste compost and household waste compost around 54% (Guivarch, 2001).

Repetitive inputs of urban wastes improve soil structure by introducing organic matter and increasing soil carbon accumulation, and thus improve water retention available for plants and soil retention against erosion. They can also stimulate the activities of microorganisms and improve the biodiversity in the soil. However, urban waste use requires careful management because complicated processes happen after having introduced the waste. The activities of microorganisms on organic nitrogen and carbon may disturb the release of mineral phosphorous. There is also the possibility of ammonia volatilization and nitrogen leaching towards groundwater, especially in sewage sludge use. Thus, it is important to match the releasing of mineral nutritional elements with the needs of plants (Dhaouadi, 2014). Another risk linked to urban waste use is the introduction of pathogens or heavy metals to soil or plants.

(3). Factors that influence on urban waste use

Land application of sewage sludge relies mainly on lands of cereal crops (wheat, barley, and corn), rape and sugar beet. Land application of sewage sludge must respect strict regulations, represented by an authorized plan that controls the area, periods, and quantity of application. In Ile-de-France Region, organic farming and vegetable cultivation forbid sewage sludge application. Green waste compost in accordance to the standard NFU 44-051 and sewage sludge compost to the standard NFU 44-095 are recognized products exchangeable in markets. In 18th and 19th century, urban waste and wastewater were largely used in the intensive vegetable cultivation systems, e.g. “mâraichage”, and the open-field cereal crops (Phlipponneau, 1956; Moriceau1994). Urban wastes are important sources of fertilizer. It was only from 20th century, agricultural use of urban waste gradually changed from a logic of agricultural fertilizer to a logic of urban waste eliminating (Joncoux, 2013).

Multiple factors influence on the supply-demand relation between peri-urban farmers and the urban population regarding agricultural use of urban wastes. Long-term use of untreated wastewater of Paris city from the end of 19th century followed by sewage sludge spreading of SIAAP caused severe soil pollution of heavy metals in the spreading zone near Achères (Mandinaud, 2005). The incident resulted in complete prohibition of food cultivation in this zone. Memories of this tragedy have important influence on social willingness in accepting urban waste in agriculture use. Some food companies and supermarkets required to avoid the use of urban waste in their contracts with farmers (Barbier and Lupton, 2003). Complaints from peri-urban residents against odor nuisance created new obstacles. In Ile-de-France, increasing use of mineral fertilizer has reduced their dependence on urban organic waste; while in developing countries, urban waste and wastewater are still important resources chased after by urban and peri-urban poor (Kurian et al., 2013; Hofmann, 2013).

At the side of urban population, there are increasing demands of waste disposal: the volume of waste keeps on increasing because of a rapid growing population (Barles, 2005); at the same time, legislation becomes stricter on the duty to collect, treat and recycle urban waste. For example, all the agglomerations of more than 2000 habitants have the duty to collect and treat wastewater according to the European Directive 91/271/EEC (CEC 1991). The Law Grenelle II (Law n° 2010-788) set the target to improve recycling rate of organic materials to 35% in 2012 and 45% in 2015. The mayor is directly responsible for waste management in his municipality. It concerns also the intermunicipal organizations and the regional authority because the regional plan of waste management (PREDMA) was adopted from 2009. It remains disputable among the different stakeholders that agriculture in Ile-de-France should strengthen its function of urban waste recycling.

2.2.3 Environmental functions for maintenance of regulating and supporting ES

Regulating ES, e.g. soil fertilization and water regulation, and supporting ES, e.g. maintenance of biodiversity and wild life habitat are important for the functioning of agro-ecosystem and the surrounding natural habitat. Environmental functions are contributions of farmers to the maintaining of these ES.

(1). Substitution of artificial inputs for ES

Agricultural transformation in the last century was a process to replace ES with artificial inputs. The regional average input of mineral fertilizer ($N+P_2O_5+K_2O$) increased from 85 Kg/ha in 1949/1950 to a climax of 397 kg/ha in 1973/1974, and diminished constantly thereafter because of the global petrol crisis between 1973 and 1985 (Académie d'Agriculture de France, 1990), until 108 Kg/ha in 2009/2010 (source: SCEES, 2010).

The mixed crops-livestock systems rely on services from microorganisms in the soil in breaking down animal manure to maintain soil fertility and soil structure. Today such farms are mainly concentrated in the zone of Brie-Latière in the department of Seine-et-Marne, representing only 7% of the farms in the region, according to the RGA of 2010. As most farms are specialized in crops, animal manure use decreased a lot. Use of urban organic wastes is also very limited as discussed above.

Pesticides were for curative treatments, but have become systematic treatments to insure a simplified farming structure of large size, simple rotation and few hedgerows (Lamine et al., 2010). About 1200 t phytosanitary products are used in one year in Ile-de-France (Natureparif, 2013). The intensive systems “Grande Culture” move towards abandonment of biological pest control, pollination, and other ES provided by the surrounding semi-natural lands to farmlands.

(2). Nitrogen leaching and pesticide drift

This substitution has resulted in dramatic degradation of ES and negative impacts to environment. Mineral fertilizers provide nutritional elements directly available for plants without the service from the soil ecosystem. As a result, the soil in Ile-de-France has a low level of carbon storage (Arrouays et al., 2001) and deficit of organic matter (Le Villio et al., 2001). A study of Fardeau et al. (1988) on the Plateau of Beauce, a typical zone specialized in “Grande Culture” in Ile-de-France, showed that the cereal fields had an annual decrease of organic matter of 2~4% during 1971~1987. Organic matter is one of the determinants of soil stability in the zone of “Grande Culture” in Ile-de-France (Le Bissonnais and Le Souder, 1995).

Mineral fertilizers also cause the problem of nitrogen leaching which contaminates the underground and surface water. Ile-de-France monitored 908 drinking water intake points from 2007 to 2012, among which, about 25% presented a nitrate concentration level higher than 37.5 mg/l, and 13% exceeded 50 mg/l, the legal limit for drinking water (AESN et al., 2014). The highest concentration of nitrate appeared in the areas where the water table was at or close to the level of the surface: the south-east part of Seine-et-Marne and north-west part of Val-d’Oise and Yvelines. The whole Region of Ile-de-France has been classified as vulnerable zone regarding water pollution caused by nitrates from agricultural sources, following the Nitrates Directive of European Commission.

Treatment of pesticide contamination is more complicated and expensive because of the variety of pesticides being used, and by-products resulted from degradation or interaction of pesticides. Pesticides and their by-products can stay in the environment for a very long time. Some pesticides are actually banned, but are still responsible for 40% of pollution cases today above 0.1μg/l, the legal limit for drinking water (AESN et al., 2014). The most affected zones are located in Seine-et-Marne, Yvelines and Val-d'Oise, similarly to nitrate pollution. Nitrate and pesticide pollution are the most important reasons for abandonment of drinking water intake points (AESN et al., 2014).

(3). Biodiversity decline

Intensive agricultural activities are among the most important reasons for biodiversity decline in Ile-de-France in the last century: use of pesticides and mineral fertilizers, deep and repeated ploughing, reduction of landscape heterogeneity and semi-natural elements. These practices have significant influences on the richness of flora and fauna, from birds to the fauna in the soil, especially species adapted for particular biotope (Le Roux et al., 2008).

In Ile-de-France, the situation is more alarming than for the neighbor regions, according to a diagnostic report of the Regional Agency for Nature and Biodiversity of Ile-de-France (Natureparif, 2013). The agricultural landscape has only 12 % of area under grass cover (grass hedgerows, meadows, fallow lands and abandoned farmlands), whereas, 20 % is the necessary limit for maintaining a functional biodiversity (Le Roux et al., 2008). This proportion even goes down to 7.3 % in Brie and Beauce, where are located half of the agricultural lands of Ile-de-France. About 50% of messicole plants have disappeared or are going to disappear. Among the 28 specialist species of birds in agricultural landscape in Ile-de-France, 5 species disappeared in the last fifty years and 7 are in threat. The population of mammals declined except for hares and deer, which have bigger tolerance to the system of "Grande Culture". The reptiles and amphibians and the invertebrate also declined in agricultural landscape.

Fig. 3-4 presents the distributions of flora species in the red list of Znieff (Natural zone of ecological interest, fauna and flora) based upon observations from 1990 to 2005 (source: CBNBP and MNHN). Agricultural zones are even more significant than urbanized areas in forming zones unfavorable for biodiversity. However, agricultural lands can have positive effects when they are near the biodiversity pools, e.g. the forests of Fontainebleau and Rambouillet and the downstream area of Seine, and the ecological network, e.g. the valleys.

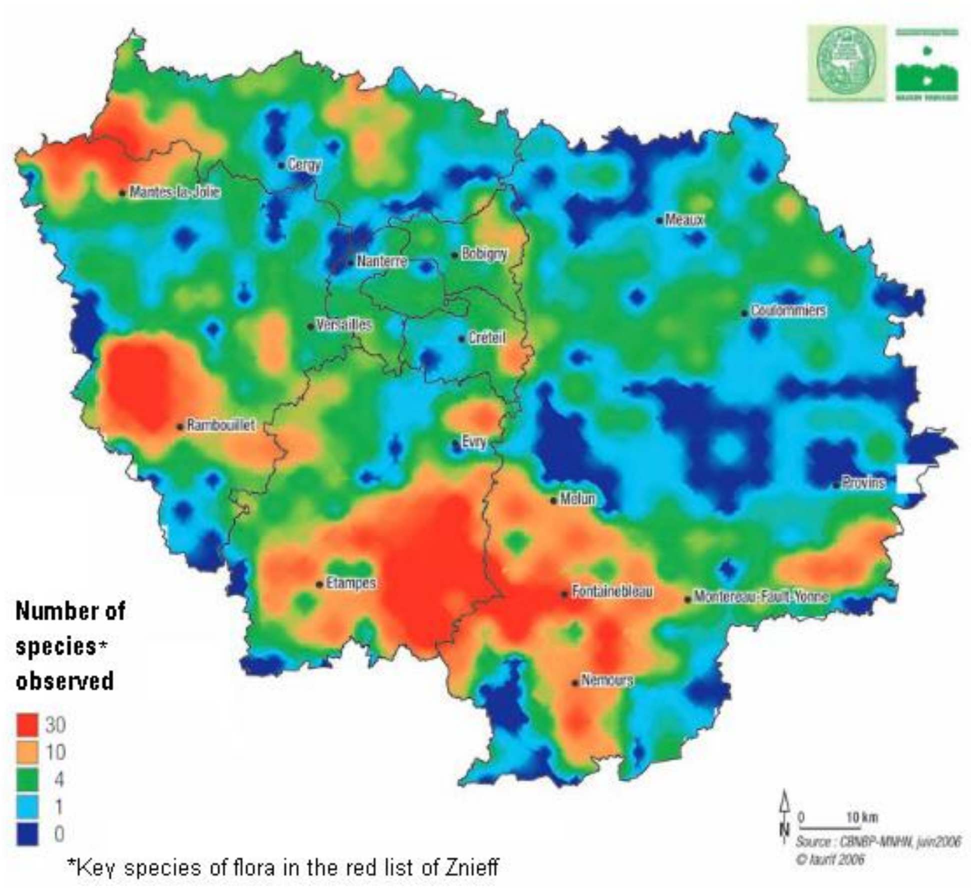


Fig. 3- 4. Distribution of threatened flora species in Ile-de-France. Observations from 1990 to 2005. Source: CBNBP, MNHN. Map made by IAURIF. *Znieff: the Natural Zone of Ecological Interest, Fauna and Flora

Decline of biodiversity, in turn, affects the delivering of multiple ES that support agricultural production, e.g. pollination, control of pests and fertilization (Le Roux et al., 2008). Biodiversity decline are mutually reinforcing with the growing dependency on exotic inputs of agriculture. An interesting solution to break the cycle is to improve the cultivated biodiversity. It means to not only diversify the species cultivated in the same lands but also manage the associated wild species, for the purpose to increase the diversity of ecological interactions (Papy and Goldringer, 2011). Studies also revealed the benefit for insects and birds by diversifying cultivated plants (Le Roux et al., 2008; Natureparif, 2013). In Ile-de-France, vegetable cultivation can have a high level of cultivated diversity. It is found that 30~130 species are cultivated in less than 10 ha of lands in the peri-urban “maraichage” system (Pourias, 2010).

(4). Soil erosion and mudflow

In Ile-de-France, the silt loam soil is sensitive to the batting of rain in the time of ploughing and sowing. The soil changes gradually from an original loose and porous state to a closed and even smooth state, and its infiltration capacity decreased from 30~50 mm/h to 1~2 mm/h (Auzet et al., 1992). The increased runoffs thus strengthen the possibility of soil erosion especially in the winter and spring when the lands are not covered by vegetation (Le Bissonnais et al., 2002). Factors that aggravate soil erosion include the increase of field size, increase of spring crops, decrease of permanent meadows, development of drainage, suppression of hedgerows and meadows on the slopes and in the valleys of floods (Auzet et al., 1992; Sogon et al., 1999). Sogon et al. (1999) did a study during four years on an agricultural catchment of 25 ha in the Brie. The result showed a net soil loss of 1 t/ha in a year to the river going out of the catchment. Because of the increasing number of habitants in the valleys in Ile-de-France, the mudflows are one of the most important natural disasters reported to the database Gaspar of the General Directorate for Risk Prevention (DGPR). Fig. 3-5 shows the average monthly incidence of mudflows based upon records from 1982 to 2014 in the database.

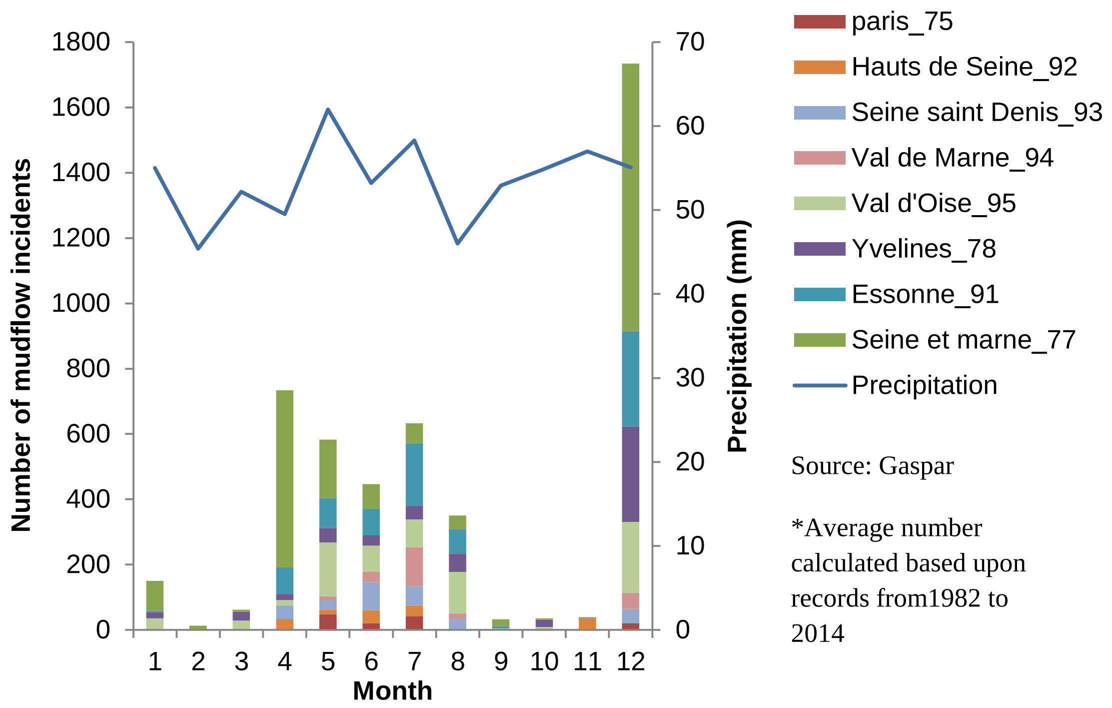


Fig. 3- 5. Average number of mudflow incidents in each month in the year

The departments in inner suburbs and Paris city had fewer incidents of mudflows and only one important period in the summer. The four outer suburban agricultural departments remarkably had two important periods of mudflows: in December and from April to August. In Seine-et-Marne, the two climaxes appeared in December and in April; in Essone, the two climaxes appeared in December and July; in Yvelines, there was only one important period in December; and in Val d'Oise, the two climaxes appeared in December and May.

The exceptionally high incidence of mudflows in December in all the departments corresponds to the period of a low level of vegetation cover after the sowing of winter crops or hoeing for the sowing of spring crops (Auzet et al., 1993). About 25% of the SAU in Ile-de-France has no vegetation cover in the winter according to estimation (Agreste, 2013a). Nitrate-fixing intermediate crops (CIPAN) are in development since 2000, but concern only 2.5% of SAU (Agreste, 2013a). The period of spring has similar situation (Auzet et al., 1993), but differences existed among the four departments, suggesting more factors. Noteworthy is that since 2000, the number of mudflow incidents are much less according to the database of Gaspar.

(5). Positive environmental impacts of peri-urban agriculture

Comparing to the highly urbanised area in Ile-de-France, agricultural lands are still in priority to be considered for environmental benefits. Farmers can provide important environmental functions by modifying their practices. Agri-Environmental Measures are encouraged for preserving biodiversity

(Natureparif, 2013) or reducing nitrate and pesticide use (AESN et al., 2014). Organic farming is an agricultural form linked to a variety of environmental issues (Lamine and Bellon, 2009). The certification “Agriculture Bio (Organic farming)” in France requires respecting more than 30 criteria including no use of pesticide, nor mineral fertiliser, preservation of biodiversity, and so on.

These instruments are still very marginally adopted in Ile-de-France. The Law of Grenelle required that organic agriculture should attain 20% of the regional SAU in 2020, but it was only 1.18% in 2009 (Toullalan, 2012). Numerous obstacles exist. For example, the sugar beets in Ile-de-France have to rely on transformation chains of conventional farming in the neighbour regions, which are obstructing the transition of sugar beets cultivation toward organic farming (Petit and Aubry, 2014). Majority of the arable farming systems do not have livestock. The transition to organic farming has a lot of technical challenges, above all, the problem of fertilization (Petit, 2013).

However, improvements are seen at least at the local scale (Natureparif, 2013). Fields border, hiking ways and the valleys are important corridors for the dispersing of species, connections among biodiversity pools and refuges of fauna and flora (Vickery et al., 2009). Hopefully, agricultural lands will be integrated into the Blue and Green network, according to the new Master Plan for Ecological Coherence (SRCE) of Ile-de-France of 2013.

Conclusions

This part has developed an integrated framework of ES and MFA for peri-urban agriculture based upon a comparative review on agricultural research working on the two strategies and application in the Region of Ile-de-France.

The comparative review suggests that there is great value in pooling the ideas and approaches of MFA and ES. The two strategies are closely related though they have different interpretations and approaches to recognize and manage multiple services and disservices from agriculture beyond production needs. Integration of MFA and ES will improve their applications in operational use and contribute to policy-making for sustainable agricultural development.

Agricultural lands in Ile-de-France Region experienced dramatic changes in the last century, under the joint influences of urbanization, agricultural modernization and agricultural policies responding particularly to a postwar context. Correspondingly, the evolution of agricultural lands distinguishes three periods:

First, in the period of continual urban expansion before 1960s, there saw decrease of COP crops (cereal, oilseeds and protein crops), forage crops and fallow lands, and increase of natural meadows, fruits and vegetables.

Second, during the period of peri-urbanization and sub-center construction in 1960s and 1970s, the consumption of agricultural lands was the fastest and there was an important quantity of land abandonment. COP crops increased and all other land use types decreased remarkably. This period founded the basic pattern of an intensified and simplified agriculture of Ile-de-France.

The third period began from 1980s. The process of peri-urbanization and sub-center construction slowed down. Agricultural lands had a much slower decrease and the structure became stable. Now, the permanent meadows and fruit cultivations remain in a small proportion. Arable lands are dominated by COP crops (80~86%), sugar beets (7~8%) and fallow lands (4~13%).

There are mainly three principal agricultural systems in Ile-de-France: the large size open-field system of “Grande Culture” composed by COP crops and sugar beets, small size but intensive vegetable cultivations and the mixed system of crops and livestock. Most of agricultural lands are located in the outer suburbs. COP crops distribute almost equivalently on the remaining farmlands. Sugar beets are mainly cultivated in three zones, respectively in the north, in the south and in the east of the region. Vegetable cultivations are mainly close to the urban agglomeration. The mixed systems of crops and livestock are marginally located, e.g. in the zone of Brie-Laitère.

The integrated framework of ES and MFA for peri-urban agriculture distinguishes four categories of ES/function combinations:

The first category includes provisioning ES and related functions. Agriculture in Ile-de-France has an extraordinary provisioning ES per hectare comparing to in other regions in France. Whereas, it does not contribute much to the local food supply, because cereal crops dominate the overall agricultural structure and the production largely goes to markets outside the region. The fresh fruits and vegetables primarily supply local markets but have decreasing areas. Animal production has lost their importance in regional agricultural land use and in meeting local needs. The average economic return to a farmer has increased remarkably, but the economic return from per unit of land is decreasing in the system of "Grande Culture". The salary of a worker is increasing but the number of workers is decreasing at the regional level. Farmers rely on the enlargement of farm size to maintain profitability.

The second category includes landscape amenity and cultural ES and related functions. The agricultural landscape in Ile-de-France has been greatly simplified in the process of agricultural modernization, but the open vast fields of "Grande Culture" are appreciated as a symbol of freedom. Agri-tourism is developing fast in peri-urban area. Agriculture is also a lifestyle appreciated by traditional farmers and urban population who cultivate family gardens. Meantime, agriculture plays an important role in building territory identity through Regional Natural Parks, Agri-Urban Projects and other instruments.

The third category includes agricultural recycling of urban wastes and the underpinning ES of waste breaking down and fertilization. In Ile-de-France, urban wastes partly or totally used in agriculture include the sewage sludge, green waste and household organic waste. Multiple factors influence on the supply-demand relation between peri-urban farmers and the urban population regarding urban waste use.

The fourth category includes the environmental functions, which characterize the contributions of farmers to the maintaining of multiple regulating and supporting ES in agro-ecosystem and surrounding semi-natural habitats. Agriculture in Ile-de-France substantially replaced ES with artificial inputs in the last century. This substitution resulted in dramatic degradation of ES and negative impacts to environment, such as degradation of soil fertility, nitrogen leaching, and pesticide drift, as well as the decline of biodiversity. However, comparing to the highly urbanized area, agricultural lands are still in priority for environmental benefits. Various instruments try to encourage farmers to enhance environmental functions, such as the Agri-Environmental Measures, labelling of organic farming, and integration of agricultural lands into the Blue and Green network.

Profitability of agriculture does not equal to its productivity. The economic value of agricultural production alone is not enough to stand against the regression of peri-urban agriculture. Integration of ES and MFA strategies will provide strong justifications and effective solutions for the preservation of peri-urban agricultural lands.

Part 2

Managing Abandoned Farmlands in Peri-Urban Area: a Multi-level Approach in the case of Ile-de-France Region

Introduction

Managing abandoned farmlands needs to understand the reason of abandonment and the reuse of abandoned lands. Peri-urban area differs from rural area in both issues.

The review of Benayas et al. (2007) distinguished the drivers of land abandonment into two categories: (i) rural-urban migration searching for new economic opportunities and (ii) ecological and mismanagement drivers, e.g. the poor soil condition. The rural-urban migration is mainly a phenomenon in rural area, leaving behind massive abandoned lands and a large number of hollowing villages (Liu et al., 2010). Peri-urban people are also attracted by the employment opportunity offered by the central city. However, urban expansion offers new economic opportunities to peri-urban lands. Increasing installation of new peri-urban residents from the city has changed the spatial and social structure in peri-urban areas (Boyer, 1988; Berger, 1989).

Peri-urbanization encourages land speculation by the owners, who themselves don’t work in the farming sector and wait to sell their lands as constructive lands (Gervais and Jaouich, 1984; Darly and Torre, 2013). Public projects also reserve large area of lands for future construction of airports, highways, and urban sub-centers (Bryant, 1986). Pointereau and Coulon (2009) estimated that 42% of abandoned lands in France located in urban area, by comparing the Utilized Agricultural Lands (SAU) and artificialized lands. The risk of abandonment increases, when the transport networks, commercial centers and residential areas fragment progressively agricultural lands, and makes farmers feel uncertain about their future (Gervais and Jaouich, 1984; Bryant, 1984, 1986; Orsini, 2012; Petit et al., 2011).

The reuse of abandoned lands depends on social needs of particular land functions. The progress of succession on abandoned lands alters the ecosystem services delivered to human society and thus results in transition of land functions. Benayas et al., (2007) found studies reporting positive effects of abandoned farmlands to biodiversity, water regulation, soil recovery, nutrient cycling, and landscape diversity, and others reporting negative effects in the same aspects. In peri-urban area, abandoned farmlands may be appreciated by urban population for their wilderness, but they also draw conflicts around illegal waste dumping and camping because abandoned lands are left “open” and unmanaged (Poulot, 2012; Darly and Torre, 2013).

Agriculture in Ile-de-France Region, according to Chapter 2, is mono-functional and disconnected with urban population. Intensification and abandonment of agricultural lands happened in parallel when development of urban infrastructure grabbed lands from agricultural sector (Bryant, 1973, 1984). Abandonment became especially severe in the periods of 1960s and 1970s when peri-urbanization and sub-center construction were implanted in the peri-urban agricultural zones. Numerous illustrations of abandoned farmlands can be found in Bryant (1984). Since late 1980s, the society shows growing resistance to urbanization and starts to recognize the multiple ecosystem services and functions from peri-urban agriculture. Reuse of abandoned farmlands has become an important subject in the local planning of urbanization and regional land use management. There is an urgent need to understand the mechanisms and multi-scale actions linked to abandoned farmlands in peri-urban area.

This part uses a multi-level approach to investigate the question of managing abandoned farmlands in peri-urban area of Ile-de-France Region. It combines a set of analyses on the regional land use pattern and interviews at two local areas about the perceptions of different actors towards abandoned farmlands. Benjamin et al. (2005, 2007) and Lieskovský et al. (2015) used similar approaches to study abandoned farmlands in a rural area of Québec (Canada) and across Slovakia, respectively. Regional pattern analysis was mainly for identification of geophysical factor and local interviews with people was for understanding the drivers of abandonment and reuse. Further research is needed to develop the approach for peri-urban studies and to better combine the two parts of analyses at different scales, so as to contribute to the management of abandoned farmlands.

This part includes two chapters. Chapter 4 describes the materials and methodology, and Chapter 5 presents the results. The analyzes on regional pattern include first a trajectory analysis (Wang et al., 2012) that identifies the principal land use changes and the distribution of land abandonment in Ile-de-France Region, based on land use data through the period of 1982-2012. Then, a classification of the municipalities according to land use change pattern and other factors try to distinguish and compare the different situations of abandonment. A third analysis at regional level is about the evolution of appearance and reuse of abandoned lands along the time. The aim of that is to reveal the temporal trends and explore the influences of particular economic, social and political events. The analysis at local level about the perceptions of different actors towards abandoned lands investigates a serial of questions: what ecosystem services or negative impacts are provided from abandoned farmlands? What do the local actors expect from abandoned farmlands? How the regional policies act on the local cases?

Chapter 4

Materials and methodology of the study on abandoned farmlands in Ile-de-France

1. Study area and selection of local study sites

Ile-de-France Region is a traditional agricultural region dominated by highly mechanized cereal crops, but also a region containing the biggest urban agglomeration of France. The present regional area has such structure that 25% is composed by urban area (buildings and infrastructures), 25% by forests and 50% by farmlands. Chapter 2 has more information on the biophysical and geographical conditions of the region.

1.1. Abandoned farmlands in Ile-de-France Region

Abandoned farmlands appear under different stages of vegetation (herbaceous, shrubs and woods) in Ile-de-France Region (Fig. 4-1). Their management involves a complicated combination of issues:

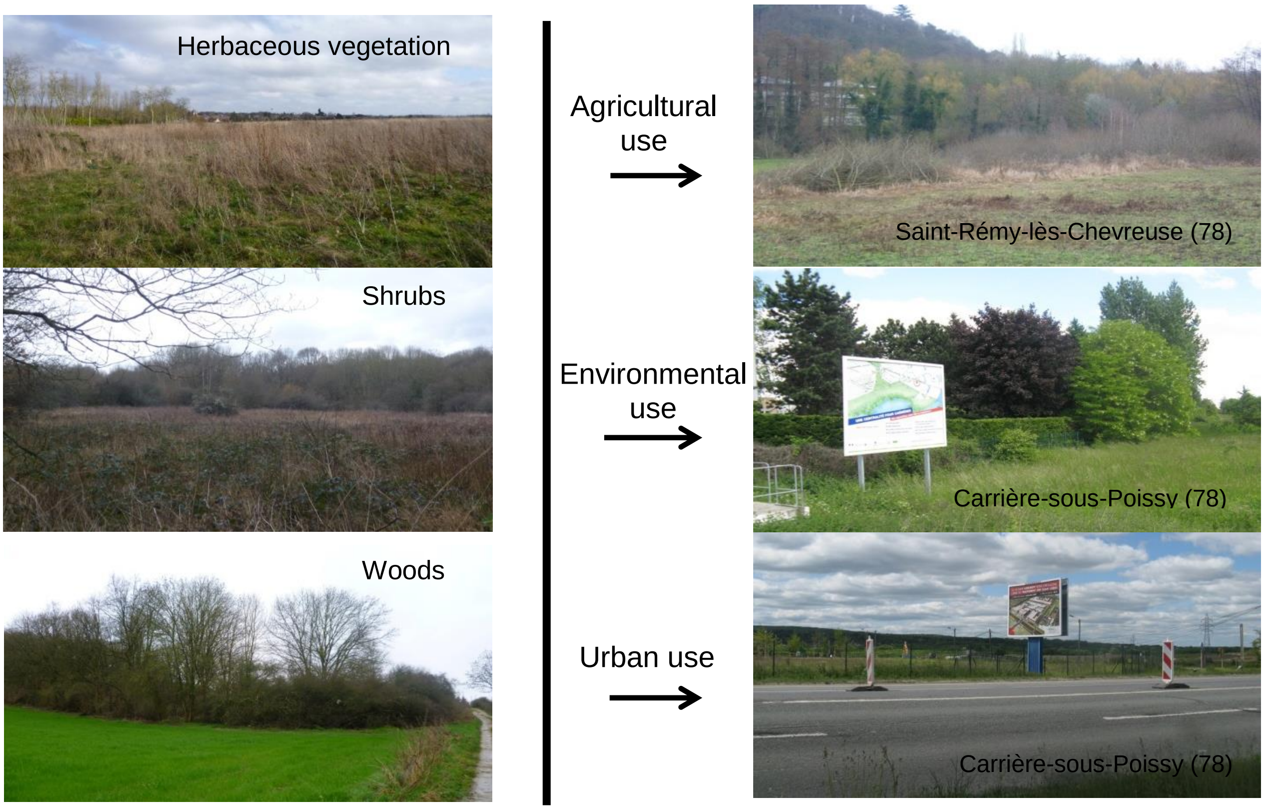


Fig. 4- 1. Abandoned farmlands in the Ile-de-France Region. Left: abandoned farmlands in different stages of vegetation succession. Right: abandoned farmlands under different choices of reuse. Source: field visit.

Rich in biodiversity and other ecological value, abandoned farmlands are integrated in the program of Green and Blue Networks (“Trame Verte et Bleue”) and the Regional Ecological Coherence Scheme (SRCE) of Ile-de-France of 2013. But the urban population has other expectations. Some prefer programs of public parks or eco-districts instead of leaving forests to develop and obstruct the view of landscape. Another possibility is the return to agriculture. The Agency of Green Spaces (AEV) has launched a variety of operations to encourage the recultivation of abandoned farmlands.

“Densification” in urbanization has been encouraged by various political measures in France since 1990s to limit the loss of agricultural lands (Darley and Touati, 2011). Abandoned lands in urban areas are thus in priority for the construction of new houses as declared by the Master Plan of Ile-de-France adopted in 2013 (SDRIF, 2013). The most concerned are abandoned lands in near suburbs enclosed by built-up area and those in land reserve zone, e.g. the area of New Towns (“Villes Nouvelles”).

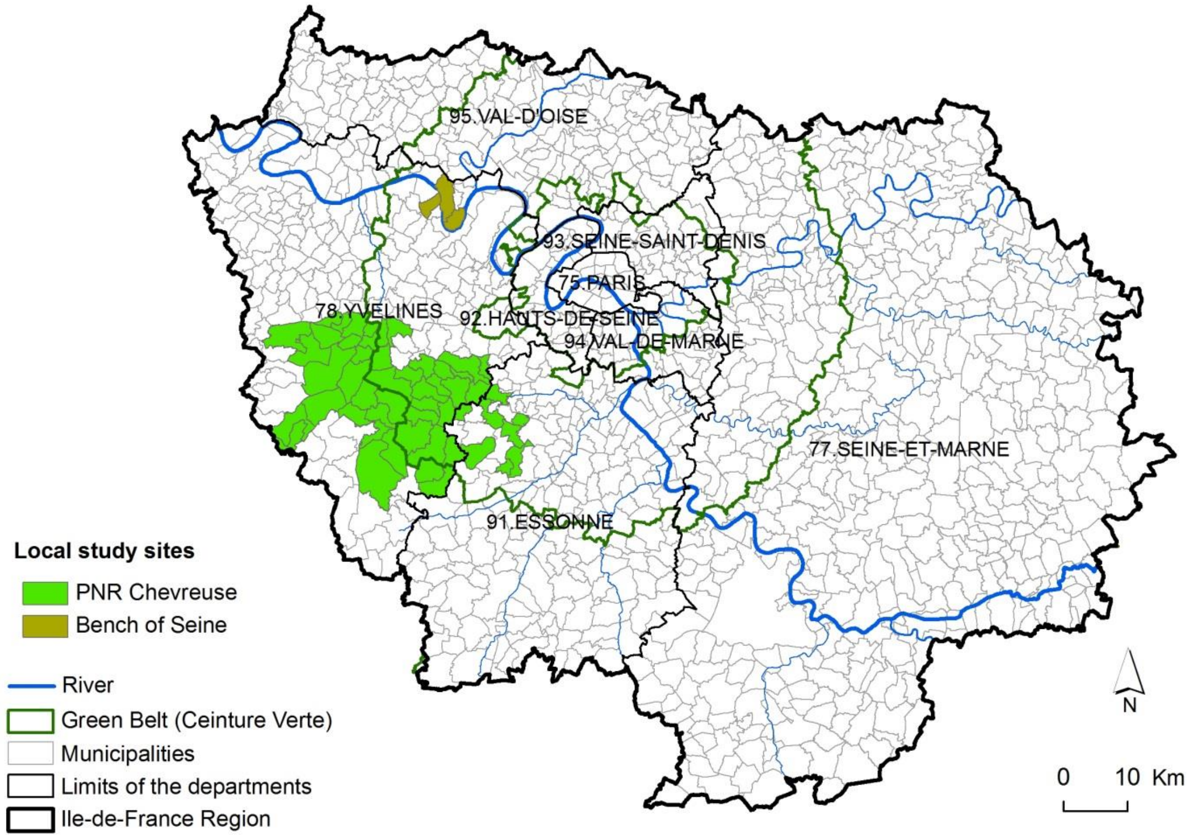


Fig. 4- 2. Study area and local study sites. The bench of Seine investigated includes three municipalities in the department of Yvelines (78): Vernouillet, Triel sur Seine and Carrières-sous-Poissy. The PNR of Chevreuse includes 51 municipalities in the department of Yvelines (78) and Essonne (91).

Different zones should have different problems in terms of land abandonment. In Ile-de-France, the three departments, namely, Hauts-de-Seine (92), Seine-Saint-Denis (93) and Val-de-Marne (94) form the inner urbanized suburbs immediately surrounding Paris, being called the “Petite Couronne” (Fig. 4-2). Other four departments, i.e. Seine-et-Marne (77), Yvelines (78), Essonne (91) and Val-d’Oise (95) form the outer rural hinterlands, being called the “Grande

Couronne”. The Agency of Green spaces initiated since 1976 a program of Green Belt (“Ceinture Verte”) of Ile-de-France, with the objective to preserve open spaces surrounding Paris in a belt between 10 and 30 km to the city center. A number of instruments contributed to its concretion and the Green Belt has become an important element in the regional planning (IAURIF, 2005). The Green Belt is managed as the frontier between the Parisian agglomeration and its rural hinterland.

In this context, drivers within agricultural sector would be more important in the rural hinterland, such as the problems of lacking successors, soil quality, and economic profit of particular agricultural activities. In the near suburbs, drivers linked to urbanization would be more important, e.g. land speculation, land expropriation and land fragmentation.

Ile-de-France Region has important area concerned by Operations of National Interest (Opérations d’Intérêt National, OIN), e.g. the New Town of Marne-la-Vallée and Sénart, the scientific and technological center Paris-Saclay, the airports of Charles-de-Gaulle, Orly and le Bourget, and the OIN Seine-Aval composed by 51 municipalities in the downstream of Seine. The Regional authority uses Master Plans to coordinate urbanization, agriculture and environment. The municipalities make their own Plans of Urbanization. Therefore, management of abandoned farmlands in Ile-de-France is definitely an issue among multiple actors at different scales.

1.2. Selection of two local study sites

Two local areas (Fig. 4-2) were selected to investigate the attitudes of different actors about the management of abandoned farmlands. One is a bench of Seine including three municipalities in the department of Yvelines (78), namely, Vernouillet, Triel sur Seine and Carrières-sous-Poissy. The other is the Regional Natural Park (PNR) of Haute Vallée de Chevreuse. The photos in Fig. 4-1 were from the two areas. They were selected also because they are in very different situations.

The bench of Seine at Triel and Carrières used to be a zone of vegetable cultivations, but was polluted by wastewater spreading of the Parisian agglomeration (managed by the station of Achères) during the whole 20th century. The zone became vast areas of abandoned lands as cultivation for human consumption is forbidden since 2000. In addition, the bench is also a typical zone of sand quarries. Vernouillet was not influenced by the pollution incident of Achères. There, agricultural lands are distributed in a zone progressively enclosed by urban areas. Now the three municipalities are inside the OIN Seine-Aval and under coordination of the Inter-municipality of 2-Rives-de-Seine (CA2RS). Several projects are created in order to manage these vacant lands, e.g. the eco-district project “Carrières-Centralité” of 47 ha, the “Coeur Vert” to cultivate miscanthus for bio-energy in an area of 57 ha, and the “Parc Départemental du Peuple de l’Herbe” for enhancing the service of ecological corridor and prevention of flooding risk.

PNR of Chevreuse was created in 1985 for the concern to protect agricultural lands against urban expansion. It is the first PNR of Ile-de-France. 19 municipalities participated at the moment of its creation and the number increased to 51 in 2011. The PNR is located in the valley of Chevreuse, the upstream of Yvette, and between the Rambouillet forest and the Hurepoix plateau. It is 20 km away from Paris and remains principally a rural area, with 47% of its area composed by forests or woods, 37% by agricultural lands and 13% by built-up area. The Charter of PNR (2011-2023) emphasizes on four aspects: biodiversity and natural resources, climate change, natural and historical heritage, and social and economic development.

2. Identification of the principal land use trajectories and abandoned lands

2.1. Land use data

The land use data were from the regular observations of MOS developed by IAURIF (Institute of Management and Urbanism of Ile-de-France Region). Chapter 2 in Part 1 has detailed description about this data base. The data includes 8 phases across 30 years (1982, 1987, 1990, 1994, 1999, 2003, 2008, and 2012). They are freely available for scientific research based upon an agreement, and are considered reliable for this study.

MOS are composed by numerous polygons in the shapefile format in Geographic Information System. The coordinate system adopted is RGF_1993_Lambert_Conformal_Conic. At the finest level, 81 different land use types were identified and coded with the number from 1 to 81. Each polygon has a unique land use type and was attributed the corresponding code. Land use polygons in different years are overlaid and intersected into smaller polygons, and thus each small polygon has a unique code for each year.

About two thirds of the 81 land use types are urban land uses, such as golf, horse center, roads, collective residence, hospitals and others. As the research interest of this study is the abandonment of farmlands, I grouped the land use types into 9 categories and coded as follows: 1. Forests and woods, 2. Semi-natural lands under herbaceous or boreal cover, 3. Arable lands, 4. Meadows, 5. Fruits, 6. Water areas, 7. Urban open spaces, 8. Urban buildings and infrastructures, 9. Construction sites and material extraction area.

Among them, urban open spaces include urban parks, family gardens, golfs, open air sports area, cemetery and others. They provide different functions and ecosystem services from those of urban buildings and infrastructures. Construction sites and material extraction areas (e.g. sand quarries) turn to be temporary disturbance to agricultural lands and result in abandoned lands in semi-natural state. Therefore, it was preferred to distinguish the categories 7, 8, and 9 than simply using one category of urban areas.

2.2. Computing and selection of the principal land use change trajectories

The spatial analyzes relied on ArcGIS 10.1 and Excel 2010. Land use change trajectories were computed according to Equation 4-1 (Wang et al., 2012) after having removed polygons that have a same code through the period from 1982 to 2012.

$$T_i = (G1)_i \times 10^{n-1} + (G2)_i \times 10^{n-2} \cdots + (Gn)_i \times 10^{n-n} \qquad \textbf{(4-1)}$$

T_i is the trajectory code of polygon *i*. *n* is the number of time nodes, and *n*=8 in this study. *G1*, *G2*, …, and *Gn* are the codes of land use types of polygon *i* in year 1, year 2, …, and year *n*.

Different from Wang et al. (2012), trajectories in same directions were grouped in this study by deleting adjacent duplicate numbers, for example, 11122233 to 123, 12233333 to 123, and 12223332 to 1232, etc. Two steps then allowed the selection of the principal land use change trajectories:

(1). Preliminary selection

As there are still more than one thousand different trajectories, I did a preliminary selection by sorting the areas of the trajectories in descending order and selected the most important ones until the accumulated area accounted for 95% of changed area in the region. The areas of polygons were obtained in ArcGIS and the areas of trajectories were summed up in Excel.

Then, I excluded the trajectories concerning only changes among urban open spaces and urban constructive lands (e.g. 78, 798, 898, …). The municipality Congerville-Thionville (Essonne, 91) showed an outstanding conversion of almost the whole municipality from abandoned farmlands (land use type code: 2) in 1982 to agricultural lands (land use type code: 3) in the following years. This was impossible according to verification on the website. It was probably an error in the database, so I adjusted this polygon as unchanged agricultural lands. 143 trajectories were kept as important after the preliminary selection.

Table 4- 1 The functions of landscape metrics (Mcgarigal, 1995; McGarigal et al., 2002)

Name	Equation	Description
Metrics at class level		
Class Area (*CA*)	$CA_i = \sum_{j=1}^{n_i} a_{ij} \left(\frac{1}{10000}\right)$	a_{ij} is the area of the j^{th} patch of the i^{th} patch type (i.e. land use change trajectory in this study). n_i is the number of patches of the i^{th} patch type. CA_i means the sum area of the i_{th} patch type. *CA* (ha) >0, without limit.
Mean Patch Area (*AREA_MN*)	$AREA\_MN_i = \frac{CA_i}{n_i}$	$AREA\_MN_i$ is the average patch area of the i^{th} patch type. *AREA_MN* (ha) > 0, without limit.
Largest Patch Index (*LPI*)	$LPI_i = \frac{\max_{1\le j\le n_i} a_{ij}}{A} \times 100$	*A* is the total area of landscape, i.e. the area of Ile-de-France Region. LPI_i equals the percentage of the regional area comprised of the largest patch of the i^{th} patch type. $0 < LPI$ (%) ≤ 100.
Aggregation Index (*AI*)	$AI_i = \left[\frac{g_{ii}}{\max \to g_{ii}}\right] \times 100$	g_{ii} is the observed number of like adjacencies of patch type *i*; $max \to g_{ii}$ is the maximum possible number of like adjacencies given the proportion of the landscape (i.e. the regional area in this study) comprised of patch type *i*. $0 \le AI$ (%) ≤ 100. *AI* = 0 when the focal patch type is maximally disaggregated; *AI* = 100 when the patch type is maximally aggregated into a single compact patch.
Metrics at landscape level		
Patch Density (*PD*)	$PD = \frac{N}{A}$	*N* is the total number of patches including all the patch types in the landscape. *A* is the area of the landscape (i.e. the area of a municipality if calculating the index at municipal level). *PD* (#/ha) > 0, without limit.
Largest Patch Index (*LPI*)	$LPI = \frac{\max_{1\le j\le n_i, 1\le i\le m} a_{ij}}{A} \times 100$	n_i is the number of patches of the i^{th} patch type. *m* is the number of patch types. *LPI* at municipal level equals the percentage of the municipal area comprised of the largest patch among all the patch types. $0 < LPI$ (%) ≤ 100.
Aggregation Index (*AI*)	$AI = \left[\frac{g_{mm}}{\max \to g_{mm}}\right] \times 100$	The same as *AI* at class level above, but all the patch types in the landscape are considered in the calculation.
Shannon's diversity index (*SHDI*)	$SHDI = -\sum_{i=1}^{m} p_i \ln p_i$	p_i is the proportion (CA_i/A) of area of patch type *i* (CA_i) divided by the total area of the landscape (*A*), *m* is the number of patch types found in the landscape. *SHDI* increases as the number of different patch types increases and/or the proportional distribution of area among patch types becomes more equitable. *SHDI* ≥ 0, without limit.

(2). A second selection based upon landscape metrics

Wang et al. (2012) developed a selection method based upon spatial pattern metrics of the land use change trajectories. The method was adopted here. I first converted the land use polygons concerned by the 143 trajectories selected in the preliminary process to raster format (attributing the trajectory code as raster value, resolution = 30m). Then I calculated landscape metrics at trajectory level/class level in Fragstat 4.2. Fragstat is free software developed for analyzing the influences of landscape pattern on ecological process and biodiversity (McGarigal and Marks, 1995; McGarigal et al., 2002). The interest of my study was to analyze land use change pattern rather than ecological process.

Drawing on the experience of Wang et al., (2012), I used four metrics as criteria for the second selection: *CA* (Class Area) > 100 ha, *AREA_MN* (Mean Patch Area) > 0.5 ha, *LPI* (Largest Patch Index) > 0.003, and *AI* (Aggregation Index) > 50. Table 4-1 explains the functions for calculating these landscape metrics.

Finally, the selection identified 35 trajectories as the principal land use changes, accounting for 74.8% of the total changed area in Ile-de-France. All the other raster pixels were assigned background value "9999".

The 35 principal trajectories can be distinguished into ten categories of land use change, and I coded them as Lcprg_1, Lcprg_2, Lcprg_3, Lcprg_4, Lcprg_5, Lcprg_6, Lcprg_7, Lcprg_8, Lcprg_9, Lcprg_10. Among them, the category Lcprg_5 is the distribution of abandoned farmlands and woodlands. Since forests are strictly protected in Ile-de-France Region, trajectories from forests to abandoned lands only appeared for very particular reasons. These lands have the same semi-natural state as abandoned farmlands, so they were also included in the statistics. Then, I extracted trajectories about the conversions of abandoned farmlands (i.e. containing the code 2) in each group and coded as Lcprgab_3, Lcprgab_4, Lcprgab_5, Lcprgab_6, Lcprgab_7, Lcprgab_10, correspondingly.

3. Classification of municipalities to identify different situations of abandonment

There are 1281 municipalities in Ile-de-France Region (Fig. 4-2). Land use decisions are usually made at the municipal level, especially through the Local Plan for Urbanism (PLU) and the delivering of construction permission (Bacconnier, 2005). The particular geographical, social and economic conditions may result in significant differences among the municipalities regarding appearance and management of abandoned farmlands. A clustering analysis was realized in the statistical software SPSS 16.0 to classify the municipalities.

3.1. Indicators used for the clustering analysis

The clustering analysis was based upon three kinds of indicators prepared at municipal level:

(1). Areas and spatial pattern metrics of the principal land use changes

First, I overlaid the raster of the ten categories of land use changes identified in the above section 2.2 with the limits of municipalities in ArcGIS. "Tabulate Area" analysis in the toolbox of "Spatial Analysis" output a table that has the area of each category in each municipality. 10 variables were thus produced: Lcprg_1, Lcprg_2, Lcprg_3, Lcprg_4, Lcprg_5, Lcprg_6, Lcprg_7, Lcprg_8, Lcprg_9, and Lcprg_10.

Then, I extracted land use change raster of each municipality with the tool "Extraction by mask" and calculate spatial pattern metrics at landscape level (i.e. in each municipality) in Fragstat. Metrics at landscape level measure the overall spatial pattern of changed area, because different land use change types are not distinguished. Four metrics were calculated: Patch Density (*PD*), Largest Patch Index (*LPI*), Aggregation Index (*AI*) and Shannon's diversity index (*SHDI*). The corresponding functions are explained in Table 4-1.

(2). Percentages of stable land uses

According to Chapter 2, urban expansion on natural and agricultural lands largely slowed down in Ile-de-France from 1980s compared to the precedent periods. Fig. 4-3 shows the distribution of lands that kept same uses (using the typology of 9 land use types) through the period from 1982 to 2012. They accounted for 85.6% of the regional area. The structure of stable lands can indicate that a municipality is whether dominated by nature, agricultural activities, or urban elements.

Four indicators were computed based upon stable land uses: (i) percentage of municipal area comprised of stable forests and woods (Ldstapr_1), (ii) percentage of stable farmlands including arable lands, fruits and meadows (Ldstapr_345), (iii) percentage of stable water area (Ldstapr_6), and (iv) percentage of urban area including urban open spaces, buildings and infrastructures (Ldstapr_78).

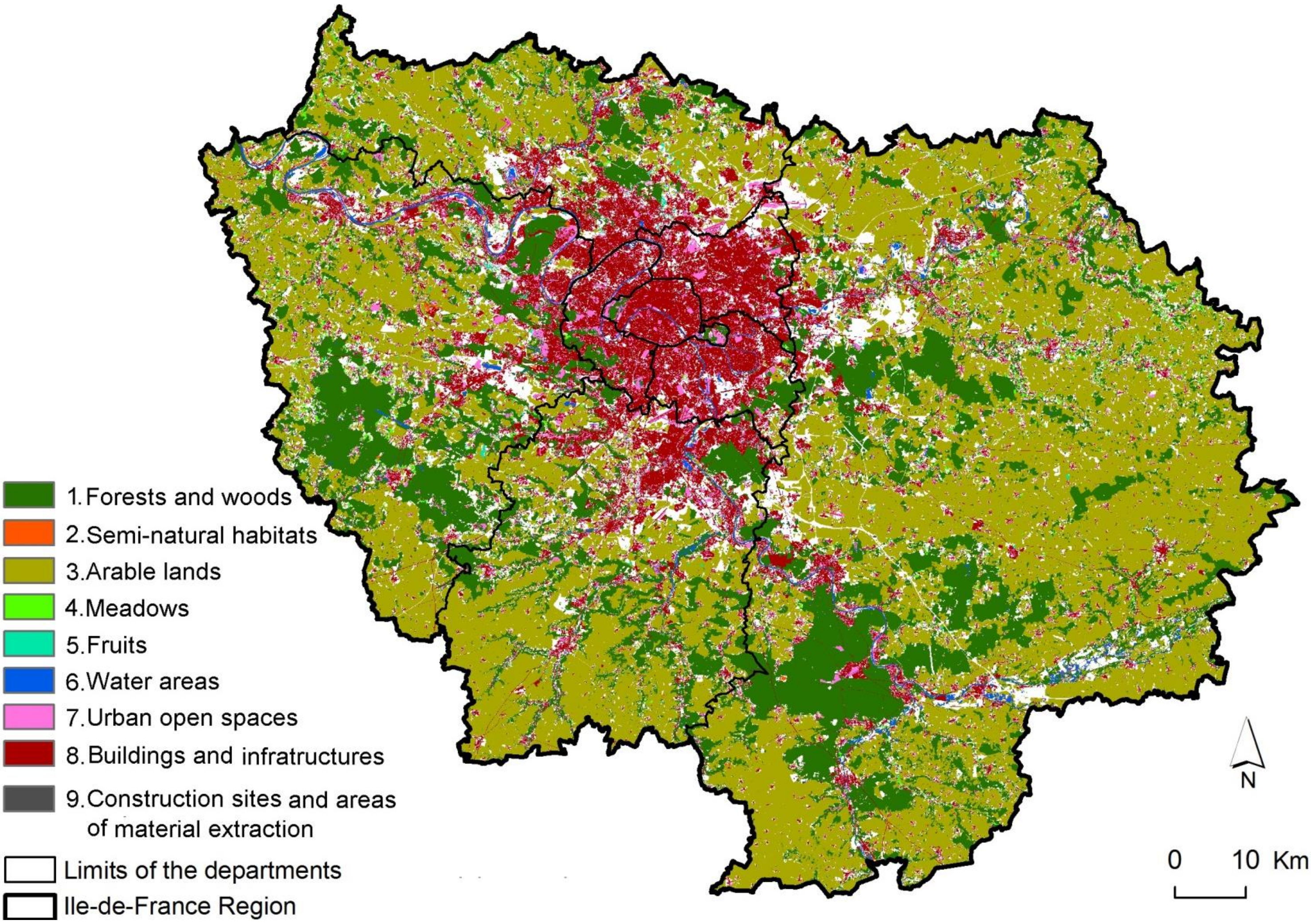


Fig. 4- 3. Stable land uses through the period from 1982 to 2012. Stable land use means that the land kept the same use (using the typology of 9 land use types) through the period.

(3). Population and number of professional farmers

Population and number of professional farmers were selected as two social factors. Fig. 4-4 shows opposite distribution pattern between the two indicators according to the data of INSEE (French National Institute of Statistics and Economic Studies). Population decreases from the center to the remote rural area while the professional farmers mainly concentrate in the eastern and southern fringe.

There is no big difference between the beginning and the end of the study period except for the fact that municipalities with a high population has increased and those with an important number of professional farmers has decreased. The level in 2010 can be more suitable to represent the true state of the municipalities. Therefore, I got two more indicators, population in 2010 (P10_POP) and the number of professional farmers in 2010 (P10_FAR).

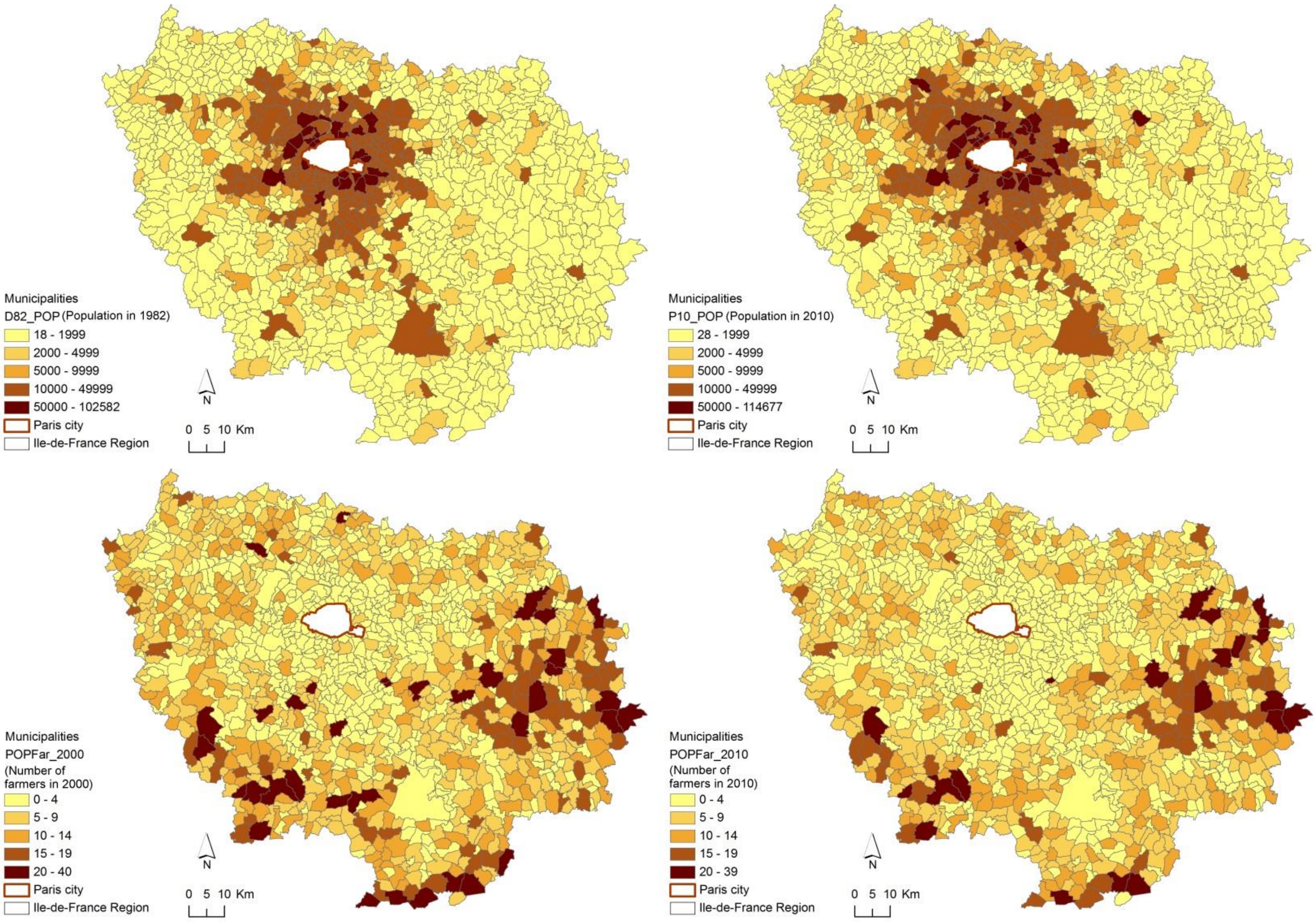


Fig. 4- 4. Population and number of professional farmers at municipal level. The legend represents the exact number of population and farmers.

3.2. Clustering analysis on municipalities

The 20 variables were imported to SPSS for clustering analysis following four steps:

(1). Normalization of indicators

Normalized Z-scores were calculated as Equation 4-2 for all the variables. n is the number of municipalities. n =1242 because several indicators could not be calculated for some municipalities closely surrounding Paris. That does not influence on the results because they are not interesting for this study. m is the number of variables, m = 20. $\bar{x}_j$ is the mean of the j^{th} variable, and σ_j is the standard deviation of the j^{th} variable.

$$Zscore_{ij} = \frac{x_{ij}-\bar{x}_j}{\sigma_j}, (i = 1, 2, \cdots, n; j = 1, 2, \cdots, m) \quad \textbf{(4-2)}$$

(2). Factor Analysis

Factor analysis was for the purpose to reduce the set of variables because uncertainties would increase rapidly in the clustering analysis when there were too many variables. Factor analysis is a statistical method searching for joint variation in response to a lower number of unobserved latent variables (called factors) from multiple observed, correlated variables. The original variables are modelled as linear combination of the potential factors (Equation 4-3).

$$X_j = \sum_{h=1}^{p} b_{hj} F_h + u_j E_j, \ \ (j = 1, 2, \cdots, m; h = 1, 2, \cdots, p) \qquad \textbf{(4-3)}$$

where $X_j = \begin{bmatrix} x_{1j} & x_{2j} & \cdots & x_{nj} \end{bmatrix}^T$, $F_h = [f_{1h} \ \ f_{2h} \ \ \cdots \ \ f_{nh}]^T$, $E_j = \begin{bmatrix} \varepsilon_{1j} & \varepsilon_{2j} & \cdots & \varepsilon_{nj} \end{bmatrix}^T$.

n is the number of municipalities. *m* is the number of variables. *p* is the number of factors. x_{ij} is the standardized original data. f_{ih} is the factor score. ε_{ij} is independently distributed error term containing variable-specific information that cannot be reflected by the factors. b_{hj} is the loading of variable X_j on F_h.

The value of the KMO Measure of Sampling Adequacy for this set of variables was 0.495 and Bartlett's Test Sig. = 0.000, so factor analysis is acceptable. Extraction of factors adopted the method of "Principal Component Analysis" on "Correlation matrix". The analysis retained 7 factors with the corresponding eigenvalue greater than 1. The cumulative part of variance explained by the retained factors reached 67.6%. A "Varimax" rotation with Kaiser Normalization then was adopted. It turned out effective because the interpretation of factors was easy.

(3). K-means Clustering Analysis (Quick Clustering Analysis)

The 7 factor scores of each among the 1242 municipalities ($F = \begin{bmatrix} f_{11} & \cdots & f_{17} \\ \vdots & \ddots & \vdots \\ f_{n1} & \cdots & f_{n7} \end{bmatrix}$) were used as input variables for clustering analysis. K-means clustering method partitions the *n* municipalities into *k* clusters ($k \le n$) in a way that minimizes the within-cluster sum of squares. Supposing that the set of clusters are S= $\{S_1, S_2, \cdots, S_k\}$, the objective is to find out:

$$\underset{S}{\operatorname{argmin}} \sum_{i=1}^{k} \sum_{F \in S_i} \| F - \mu_i \|^2 \qquad \textbf{(4-4)}$$

where μ_i is the mean of F in each cluster. *k* should be subjectively indicated by the researcher, so a serial of clustering analyses were performed with *k* = 5, 6, 7, 8, and 9. The clustering result of *k* = 7 was the best and presents a clear, comprehensible regional pattern. 4 clusters represent four different groups of municipalities and the other 3 clusters contain only several extreme cases.

(4). Non-Parametric Test (Mann-Whitney Test)

In order to test the validity of the classification, a number of 20 $\times C_4^2$ non-parametric tests between "2 Independent Samples" were carried out between each pair of groups in SPSS using the original raw data of the 20 variables. The null hypothesis to be rejected is that two samples come from the same population. Parametric tests were not used because most of the variables rejected the homogeneity of variance (HOV) assumption. Concretely, the method adopted was Mann-Whitney U Tests. The test arranges all the observations from the two groups to be compared in order of magnitude and marks the rank of each observation. It tests the null hypothesis that the median of ranks of one group is the same as the other group. It calculates U statistic as Equation 4-5-1.

$$\mathrm{U} = \min(U_1,\ U_2),\ \ where\ \ \mathrm{U}_i = n_1 n_2 + \frac{n_i(n_i+1)}{2} - S_i,\ \ (i = 1, 2) \qquad \textbf{(4-5-1)}$$

$$\text{if U } > n_1 n_2/2\,, then\ U' = \ n_1 n_2 - U \qquad \textbf{(4-5-2)}$$

$$\text{if } n_1 n_2 > 400 \text{ or } n_1 n_2/2 + \min(n_1, n_2) > 220,\ \ \mathrm{z} = \frac{U - m_U}{\sigma_U} \qquad \textbf{(4-5-3)}$$

n_1, n_2 are the number of observations in the two groups. S_1, S_2 are the sum of ranks of the observations in each group. When U is larger than $n_1 n_2/2$, U statistic is adjusted as Equation 4-5-2. For large samples, U is approximately normally distributed, so z statistic term is used, as shown by Equation 4-5-3. m_U and σ_U are the mean and standard deviation of U, respectively. The calculation of the two values is mainly based on n_1, n_2 with an adjustment to the standard deviation in the presence of tied ranks. The full formula can be found in the manual of SPSS.

Effect size measures the magnitude of differences between two groups. The calculation used the simplified rank-biserial coefficient of correlation proposed by Hans Wendt (1972):

$$r_U = 1 - \frac{2U}{n_1 n_2} \qquad \textbf{(4-6)}$$

3.3. Comparing the phenomenon of abandonment in the four groups of municipalities

Similarly, I carried out Mann-Whitney Tests to see if the four groups of municipalities are significantly different from each other regarding the conversions of abandoned lands. The comparison based upon 6 variables representing the area of six conversions, respectively (Lcprgab_3, Lcprgab_4, Lcprgab_5, Lcprgab_6, Lcprgab_7, and Lcprgab_10, see section 2.2 for the signification of variables), and a variable of the municipal area (Area_Com).

The four groups of municipalities turned out to be in different situations regarding land abandonment. The comparison resulted in interesting findings by referring to Google street view, field visit and municipal documents (e.g. the PLU) for concrete examples and verifications.

4. Temporal evolution in the appearance and reuse of abandoned farmlands

Time serials of the appearance and reuse of abandoned farmlands identify the temporal trends and political or social factors linked to particular years. The analysis was based upon 12 trajectories concerning abandoned farmlands among the 35 principal trajectories identified in section 2.2. I first assigned a code to each conversion in a particular period according to Table 4-2. The conversions include mainly the abandonment of forests, arable lands and meadows, and the reuse of abandoned lands for forests or woods, arable lands, meadows, urban open spaces and urban constructive lands (i.e. buildings and infrastructures).

These conversions were summed up for each group of municipalities identified in section 3.2 and for Ile-de-France Region in the total to compare the flows into and out abandoned lands.

Table 4- 2 The codes of land use conversions in different periods

	Time periods						
Land use conversions	1982-1987	1987-1990	1990-1994	1994-1999	1999-2003	2003-2008	2008-2012
12-	121	122	123	124	125	126	127
32-	321	322	323	324	325	326	327
42-	421	422	423	424	425	426	427
21-	221	222	223	224	225	226	227
23-	231	232	233	234	235	236	237
24-	241	242	243	244	245	246	247
27-	271	272	273	274	275	276	277
28-	281	282	283	284	285	286	287

*12-, 32-, 42- are conversions to abandoned lands from forest, arable lands and meadows, respectively. 21-, 23-, 24-, 27-, 28- are reuse of abandoned lands for forests or woods, arable lands, meadows, urban open spaces and urban constructive lands (i.e. buildings and infrastructures), respectively.

5. Interviews with different actors in two local areas

5.1. Carrying out the interviews

Interviews were carried out in the two local areas described in section 1.2, and finally in all the 3 municipalities in the bench of Seine (Vernouillet, Triel-sur-Seine and Carrières-sous-Poissy) and 6 in the PNR of Chevreuse (Cernay-la-Ville, Le Perray, Auffargis, La Celle-les-Bordes, Saint-Rémy-L'Honoré, Saint-Rémy-lès-Chevreuse). A group of Master's students from the University of Paris X[†] accomplished the interviews.

We tried to get the attitudes of different actors: (i) 1 elected representative, 2~6 residents and 1~2 farmers for each municipality, and (ii) 1 environmental association in each study area. The individual meeting with each actor lasted from 30 minutes to 2hours. Questionnaires were designed to guide the conversation and were slightly different according to the category of actors (see Appendix 2~5 for the questionnaires for elected representative, residents, farmers and environmental associations).

The principal questions included: (i) the location of abandoned farmlands in relation to the interviewee's activities (near his/her house, in his/her fields of cultivation, location in the municipality…), (ii) perceptions of the interviewee towards abandoned lands (positive images or negative impacts), (iii) understanding of "ecosystem services" provided by abandoned lands, (iv) willingness in the management of abandoned lands.

Besides semi-direct conversations, the interviewees were invited to fill three tables (Appendix 6, 7 and 8). The first table is about their knowledge of abandoned farmlands. The second is about the potential uses of abandoned farmlands. The last is about their feelings towards abandoned farmlands. Each table proposed a list of items (each person should choose no more than 5 items) and was open for new items proposed by the interviewee himself. None of the interviewees proposed new item. Similar items appeared in different tables with the purpose to make sure if their responses were consistent.

[†] Borderieux J., Carollo J., Chali J.-M., Dagonet V., Gauguet J., Steenkiste F., Zade T., 2014. La friche agricole: des services écosystémiques en mal de reconnaissance sociale ? Report realized in the frame of a Master' program approved by the University of Paris Ouest Nanterre La Défense in April 2014.

We obtained a total of 49 complete interviews (see Appendix 9 for a summary of the background information of the interviews).

5.2. Analysis of the interviews

Profound qualitative analyses were performed to compare the perceptions of different actors in two different local areas, in order to contrast with the results of regional spatial analyses. Transcription of the actors' conversations allowed distinguishing the convergences and divergences.

I also performed quantitative analyses with the binary table (Table 4-3, see Appendix 10 for all the actors) representing the principal ecosystem services (ES) and disservices (DS) from abandoned farmlands perceived by each actor, and their opinions about the future use of these lands: "yes (1)" or "no (0)" for having perceived the ES/DS, for using abandoned lands for construction, agricultural activity, ecological habitats and recreational parks, respectively.

Table 4- 3 Perceptions on ecosystem services (ES), disservices (DS) and reuse of abandoned farmlands (part, see Appendix 10 for all the actors)

	ES1	ES2	ES3	ES4	ES5	ES6	ES7	ES8	DS1	DS2	Uagr	Uurb	Ueco	Urec	Area
A1	1	1	1	1	0	0	1	0	1	0	1	0	0	0	1
A2	0	0	0	0	0	0	1	0	0	0	0	0	1	0	1
A3	0	1	1	0	0	1	1	0	1	0	1	0	0	1	1
A4	1	1	0	1	1	1	1	0	0	0	0	0	0	0	1
A5	1	1	1	0	0	0	1	0	0	0	1	0	0	0	1
A6	0	1	1	0	1	0	0	0	1	1	1	0	0	0	1
As7	1	1	0	1	1	0	1	1	1	0	1	0	1	0	2
E1	1	1	0	1	1	1	0	0	1	0	0	0	0	1	1
E2	1	1	1	1	0	0	0	1	1	0	1	0	0	0	1
E3	1	1	1	1	0	0	0	0	0	0	1	0	1	0	1
E4	1	1	1	1	0	0	1	0	1	1	0	0	0	1	1
E5	0	1	0	0	1	1	1	1	0	0	1	0	1	1	1
E6	0	1	1	1	1	0	1	0	1	0	1	0	0	0	1
E7	1	1	1	0	1	0	0	1	1	0	1	0	1	0	2
E8	0	1	0	1	0	0	0	0	0	1	1	1	0	0	2
E9	0	1	0	0	0	1	1	0	1	0	1	0	1	1	2
H11	0	1	0	0	1	1	1	1	0	0	1	0	0	1	1
H21	0	1	0	0	0	0	0	0	0	0	1	1	0	0	1
H31	0	1	1	0	1	0	0	0	1	0	1	0	0	1	1
H41	0	1	0	1	1	0	0	1	1	0	1	0	0	0	1
H51	1	1	1	1	1	0	1	0	0	1	0	0	0	0	1
H61	0	1	1	0	1	0	1	1	1	0	1	0	1	0	1
H71	1	1	1	0	1	1	1	1	0	0	1	0	1	0	2
H81	1	1	1	1	0	0	1	0	1	0	1	0	0	0	2
H91	0	1	1	1	0	0	1	0	1	0	0	0	0	1	2

Notes: ES1: biodiversity; ES2: wildlife habitats; ES3: pollination; ES4: water or climate regulating; ES5: resistence to natural risk; ES6: entertainment; ES7: Education; ES8: esthetic service; DS1: illegal waste dumping or camping; DS2: obstruction of landscape; Uarg: used as agricultural lands; Uurb: used for urbanization; Ueco: protected for ecological interest; Urec: used for recreation. Area1: PNR Chevreuse; Area 2: Bench of Seine at Triel. The label of actors is marked by a letter (H: habitants; A: farmers; E: municipal authorities; As: environmental associations), followed by the code of municipalities (1. Cernay-la-Ville, 2. Le Perray, 3. Auffargis, 4. La Celle-les-Bordes, 5. Saint-Rémy-l'Honoré, 6. Saint-Rémy-lès-Chevreuse, 7. Vernouillet, 8. Triel-sur-Seine, 9. Carrière-sous-Poissy) and then the order of actors in the same municipality if more than one actors were interviewed. For example, H75 means the fifth habitants interviewed in Vernouillet.

The binary table was extracted from the three original tables filled by the interviewees (see Appendix 6~8), based upon a hierarchical clustering analysis in SPSS to detect items reflecting similar information and referring to classic literature on ES (Costanza et al, 1997; MEA, 2005).

A "Hierarchical clustering" analysis in SPSS based upon the binary notes of ES and DS distinguished three groups of actors. "Hierarchical clustering" seeks to build a hierarchy by progressively merging clusters according to the similarities or dissimilarities between different cases. The analysis here adopted the "average linkage between groups" method, so the distance between two subsets V and W is computed as the Function 4-8, i.e. the average of all pairwise distances between the individuals in cluster V and individuals in cluster W:

$$\mathrm{D}(V,W) = \frac{1}{|V||W|}\sum_{v\in V}\sum_{w\in W} dist(v,w) \qquad (4\text{-}8)$$

The distance (i.e. dissimilarity) between two individuals was measured by Lance-Williams distance. It is also known as Bray-Curtis distance. Table 4-4 shows the contingency table which defines the basic indicators for all kinds of binary dissimilarity measures (Choi et al., 2010). *a*, *b*, *c*, and *d* indicate the number of responses for which the interviewee v matches or dis-matches with the interviewee w. Taking H11 and H12 as an example, $a = 2$, $b = 4$, $c = 2$, and $d = 1$. Then the Lance-Williams distance is computed with Equation 4-9. It gives double weight to matches and the joint absences are excluded.

Table 4- 4 Operational Taxonomic Units expressions to compute dissimilarity between binary sets

		Interviewee *v*	
		Yes/Present (1)	No/Absent (0)
Interviewee *w*	Yes/Present (1)	*a*	*b*
	No/Absent (0)	*c*	*d*

$$\mathrm{dist}\,(\mathrm{v},\mathrm{w}) = \frac{b+c}{2a+b+c} \qquad (4\text{-}9)$$

Then, a binomial test (test p = 0.5) was carried out in SPSS on each ES/DS and each possibility of reuse, to test if the predominance of a positive response or negative response is statistically significant. For example, we have 22 positive responses (value = 1) and 27 negative responses (value = 0) for the ES of biodiversity, but the population does not necessarily have more negative perceptions. By comparing between the tests separately carried out for two areas, and among the three groups of actors, we can observe the differences between two local areas and characterize the three groups identified by clustering analysis. The null hypothesis of a binomial test is that two categories of responses (Yes/No) are equally likely to occur. A two-tailed exact probability for the error to reject Ho is calculated as Function 4-10:

$$\mathrm{Sig.} = 2\left(\sum_{j=0}^{m}\binom{N}{j}p^{*i}(1-p^{*})^{N-j}\right) - \binom{N}{m}p^{*m}(1-p^{*})^{N-m} \qquad (4\text{-}10)$$

where, for n_1 and n_2 as the number of observations in category 1 and 2, $N = n_1 + n_2$, $m = \min(n_1, n_2)$. p is the test probability, set as 0.5 in this study. $p^* = p$ if $m = n_1$; $p^* = 1 - p$, if $m = n_2$. For large N, an approximate probability based on standard normal distribution is reported.

Chapter 5

Results of the study on abandoned farmlands in Ile-de-France

1. Principal land use changes and the distribution of farmland abandonment

1.1. The principal land use change trajectories

The study identified 35 principal land use trajectories during the period from 1982 to 2012 in Ile-de-France and reclassified them into ten categories. Table 5-1 presents these trajectories and describes their spatial pattern metrics. The identified changes represented 74.8% of the total changed area, which itself represented 14.4% of the regional area.

(1). Principal categories of land use changes

The conversion from arable lands towards meadows/fruits (Lcprg_1) was the most significant, representing 20.8 % of the changed lands in the region. The opposite conversion from meadows/fruits towards arable lands (Lcprg_2) was only 7% of changed lands. Conversions of agricultural and natural lands towards urban constructive lands (Lcprg_3) and urban open spaces (Lcprg_4) were also remarkable, representing 12.8% and 14.7% of the changed lands, respectively. Area of abandonment (Lcprg_5) plus area in the risk of abandonment (Lcprg_10) accounted for 12.8%, equal to the conversion towards constructive lands. Conversions to forests/wood lands, agricultural lands (mainly arable lands) and water area were only in small proportions, representing 3.7%, 1.2%, 1.2% respectively. Another 0.5% had the conversion from urban open spaces to arable lands, which probably resulted from misinterpretation of grasslands in the airports of MOS, according to the following analysis in section 2.2 of this chapter.

(2). At the trajectory level

Arable lands were in the greatest loss, because the three most important trajectories all were conversions from arable lands to other uses, namely, to meadows (luct_34, 23694 ha), to constructive lands (luct_38, 15748 ha), and to urban open spaces (luct_37 and luct_378, 12806 ha). In addition, abandonment of arable lands (luct_32, 7229 ha) made up almost half of the total lands abandoned. Arable lands were partly compensated from meadows (luct_43, 8897 ha).

The second most important phenomenon was the reuse of abandoned lands, as urban constructive lands (luct_28, 3670 ha), urban open spaces (luct_27, 3634 ha) or forest/woods (luct_21, 3376 ha), but much less area was reused for cultivation (luct_23, 1454 ha).

Table 5- 1 The principal land use change categories and spatial pattern metrics of trajectories

Categories	Descriptions	Per. in changed lands (%)	Trajectories	CA (ha)	AREA _MN (ha)	LPI	AI	Per. in each category (%)
Lcprg_1	Arable lands →meadows or fruits	20.8	luct_34	23694.1	1.7	0.012	70.7	75.5
			luct_343	5346.7	1.9	0.003	72.7	17.0
			luct_35	1747.1	1.8	0.005	75.7	5.6
			luct_353	607.1	2.0	0.006	77.3	1.9
Lcprg_2	Meadows or fruits →arable lands	7.1	luct_43	8896.9	2.8	0.022	77.6	83.3
			luct_53	1787.1	2.2	0.013	76.7	16.7
Lcprg_3	Farmlands or natural lands →urban constructive lands	12.8	luct_38	15748.0	1.4	0.016	70.1	81.1
			luct_28	3670.1	0.6	0.003	58.5	18.9
Lcprg_4	Farmlands or natural lands → urban open spaces	14.7	luct_37	10748.0	1.1	0.019	66.7	48.3
			luct_27	3633.5	0.7	0.008	57.5	16.3
			luct_17	2502.8	0.5	0.006	54.4	11.2
			luct_378	2058.2	0.8	0.005	62.5	9.2
			luct_47	1914.4	0.7	0.006	59.9	8.6
			luct_327	946.5	0.8	0.004	58.3	4.2
			luct_347	472.1	0.5	0.004	57.4	2.1
			luct_292	641.5	1.6	0.003	73.5	4.1
Lcprg_5	Abandonment of farmlands or natural lands	10.4	luct_32	7228.8	1.2	0.011	68.8	45.9
			luct_12	2470.1	0.9	0.004	62.9	15.7
			luct_42	1957.0	1.0	0.003	64.3	12.4
			luct_342	1905.7	1.2	0.004	68.4	12.1
			luct_92	1425.0	2.3	0.008	76.3	9.1
			luct_3242	111.5	1.6	0.003	74.1	0.7
Lcprg_6	Farmlands or abandoned lands → forest lands or wood lands	3.7	luct_21	3376.4	0.7	0.003	57.9	60.1
			luct_31	841.2	0.5	0.004	55.9	15.0
			luct_41	803.2	0.6	0.004	53.1	14.3
			luct_421	597.0	0.9	0.006	62.2	10.6
Lcprg_7	Abandoned lands→arable lands	1.2	luct_23	1453.9	0.5	0.005	55.5	78.7
			luct_93	393.6	3.6	0.020	86.5	21.3
Lcprg_8	Farmlands → water area	1.2	luct_36	1442.3	1.8	0.005	76.9	81.5
			luct_96	327.7	3.0	0.004	78.9	18.5
Lcprg_9*	Urban open spaces→arable lands	0.5	luct_73	560.2	0.6	0.003	61.8	78.4
			luct_737	154.2	1.2	0.006	78.7	21.6
Lcprg_10	Farmlands in the risk of abandonment	2.4	luct_39	1721.1	3.4	0.013	81.4	48.0
			luct_393	591.7	1.7	0.003	74.7	16.5
			luct_323	1269.5	1.2	0.005	69.8	35.4
Total		**74.8**		**113043.6**				

* CA: Class Area. AREA_MN: Mean Patch Area. LPI: Largest Patch Index. AI: Aggregation Index. Codes of land use types: 1. Forests and woods, 2. Semi-natural lands under herbaceous or boreal cover, 3. Arable lands, 4. Meadows, 5. Fruits, 6. Water areas, 7. Urban open spaces, 8. Urban buildings and infrastructures, 9. Construction sites and material extraction area. The conversion from urban open spaces to arable lands (Lcprg_9) probably resulted from misinterpretation of grasslands in the airports of MOS (see section 2.2. in this chapter).

(3). Spatial structure

These land use trajectories had quite different spatial structure. A first group of trajectories had large Mean Patch Area (AREA_MN), Largest Patch Index (LPI) and Aggregation Index (AI), which suggested a pattern composed by small number of big patches. This group included conversions from meadows and fruit lands to arable lands (luct_43, luct_53), and conversions between sand quarries/project areas and arable lands (luct_93, clut_39 and luct_92).

A second group of trajectories had also high LPI and AI, but smaller AREA_MN than the first group, which suggested a mix of some big patches and small patches. This group included conversions from arable lands to urban uses and to abandoned lands (luct_38, luct_37 and luct_32).

A third group of trajectories had small AREA_MN, LPI and AI, which suggested a pattern composed by small patches. This group included especially the conversions to urban open spaces except for that from arable lands (luct_17, luct_27, luct_327, luct_347, and luct_47), conversions to forests/woods (luct_21, luct_31 and luct_41), and use of abandoned lands as constructive lands (luct_28) or cultivation (luct_23).

The results indicate that urbanization grabbed arable lands in masse in the form of big projects for urban construction or urban open spaces. Comparing to construction projects, urban open spaces integrated more dispersed small patches from different types of lands. Abandonment of arable lands happened in the form of big patches but reuses of abandoned lands were in the form of small patches.

1.2. Spatial distribution of land use changes and abandoned farmlands

Fig. 5-1 shows the distribution of the ten categories of land uses. Conversions from agricultural and natural lands towards urban open spaces and constructive lands principally happened in a belt in the near suburbs. This belt of urbanization connected the urban sub-centres (New Towns, "Villes Nouvelles") and the airport Charles-de-Gaulle. Changes within agricultural lands, i.e. between arable lands and meadows/fruits, were located in the outer suburbs which had stronger rural characteristics.

Fig. 5-2 shows the distribution of trajectories concerning abandoned lands. Similarly, in the belt of urbanization there were more abandoned lands convert to urban constructive or open spaces; and in the outer suburb area, conversions of abandoned lands were more dispersed.

Municipalities are often the basic unit of land use decision-making. In order to facilitate the comparison between the spatial pattern of land abandonment and those of its management, Fig. 5-3 presents the municipal areas comprised by different categories of conversions about abandoned lands.

Municipalities with important land abandonment appeared in both near suburbs and outer suburbs. Then, the municipalities that convert the most abandoned lands to urban constructive lands or open spaces concentrated in a certain degree near the agglomeration center. It appeared that the zone with a high flow from abandoned lands to constructive lands did not always coincident with the zone with a high flow to urban open spaces. Use of abandoned lands as urban open spaces spread more widely towards the rural fringe of the region.

As for reforestation on abandoned lands, the municipalities highly concerned were primarily located in the western part of the region and surrounding the Fontainebleau Forests in the eastern part. Return of abandoned lands to agriculture concerned fewer municipalities, mainly located in Seine-et-Marne in the eastern part of the region and several municipalities in the west, e.g. Juziers (78) and Thiverval-Grignon (78).

Therefore, the municipalities were in different situations in terms of land abandonment and its management. Classification of municipalities would be necessary to distinguish these situations and compare the respective problems linked to the management of abandoned lands.

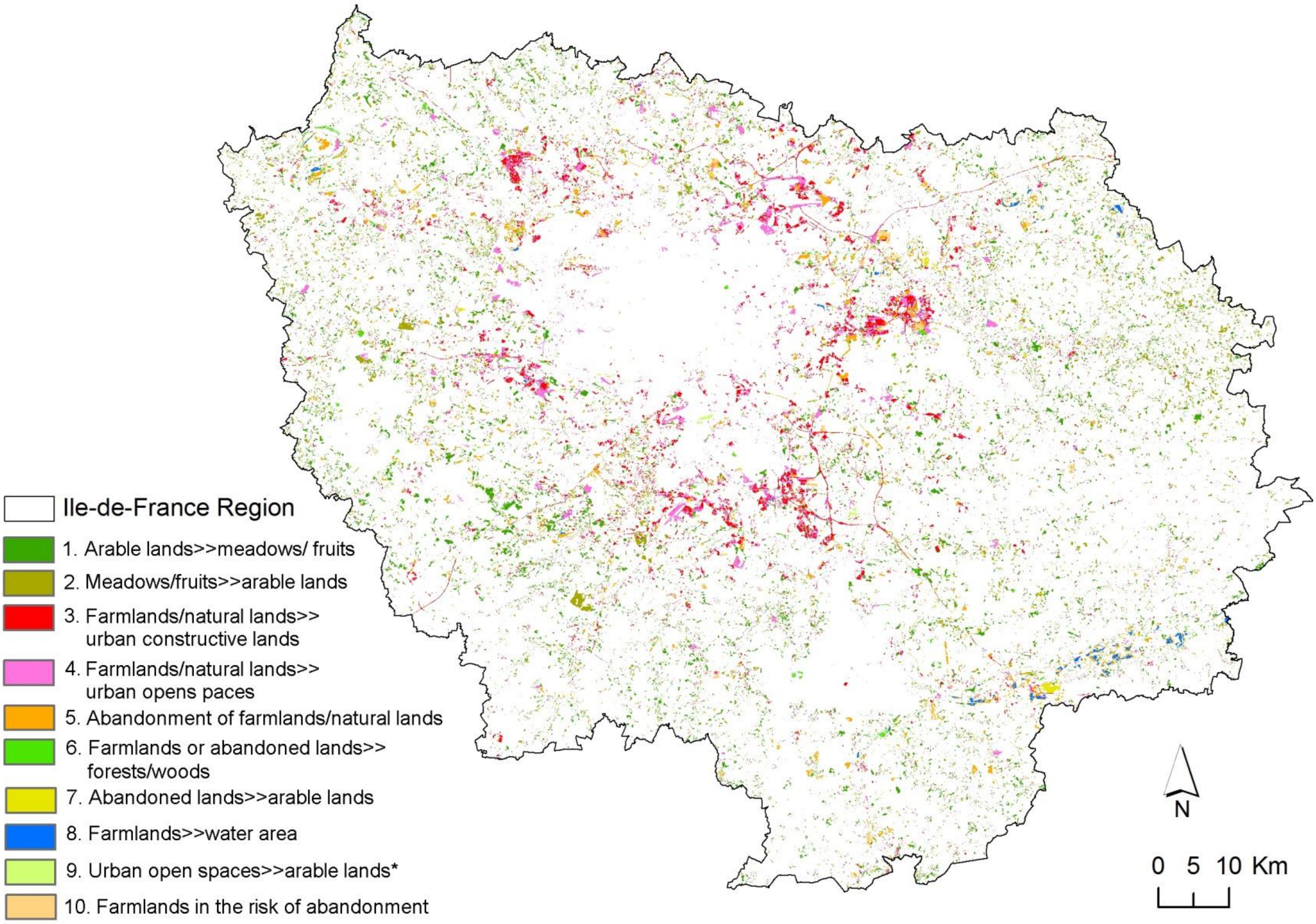


Fig. 5- 1. Distribution of the principal categories of land use change (1982-2012) in Ile-de-France Region. The conversion from urban open spaces to arable lands probably resulted from misinterpretation of grasslands in the airports of MOS (see section 2.2. in this chapter).

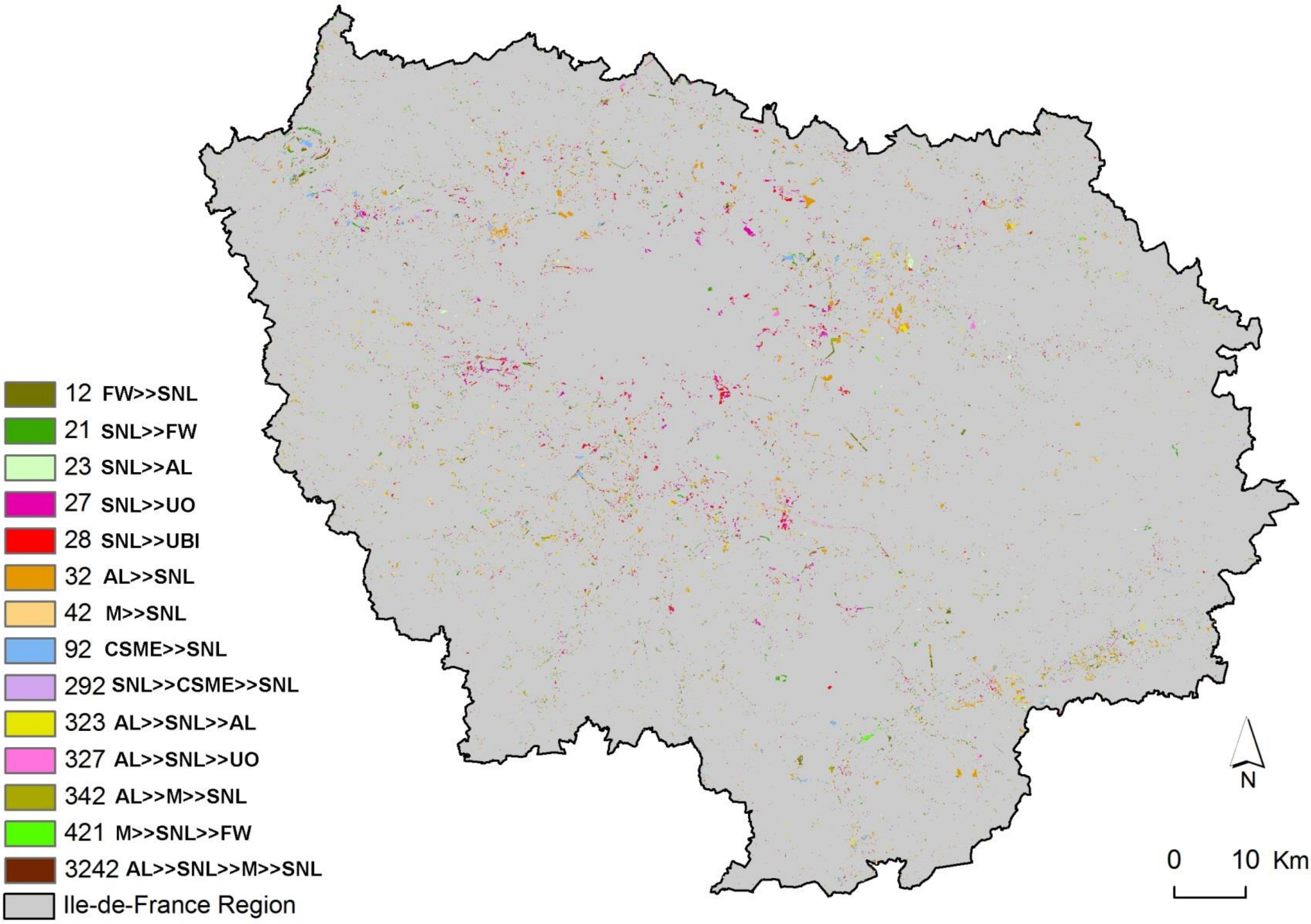


Fig. 5- 2. Distribution of the principal land use trajectories (1982-2012) of abandoned farmlands. Codes of land use types: 1(FW), forests or woods. 2(SNL), semi-natural lands. 3(AL), arable lands. 4(M), meadows. 7(UO), urban open spaces. 8(UBI), urban buildings and infrastructures. 9(CSME), Construction sites and areas of material extraction.

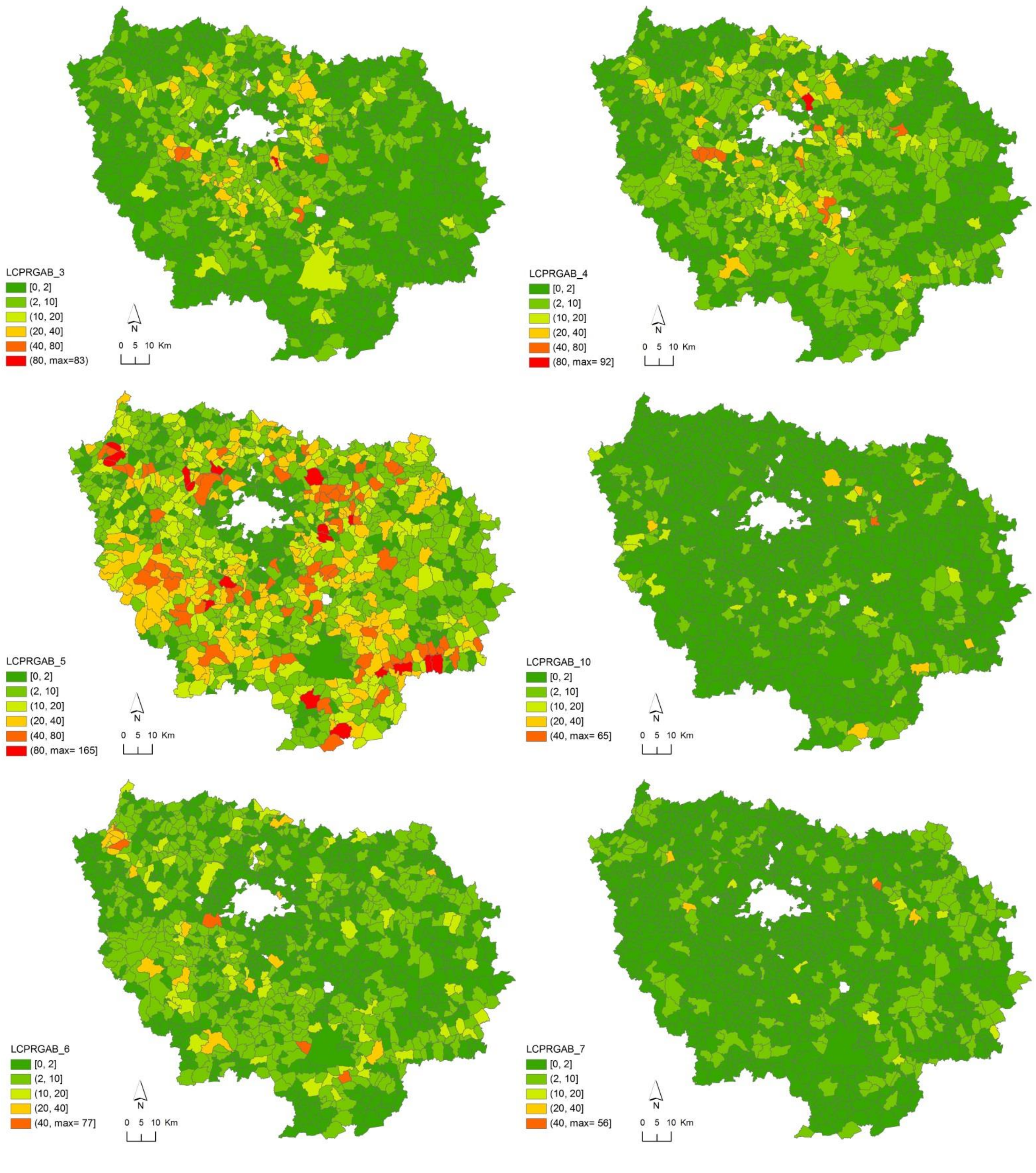


Fig. 5- 3. The area of the different conversions of abandoned farmlands at municipal level (Unit: ha). Lcprgab_5: abandonment, Lcprgab_10: area in the risk of abandonment, Lcprgab_3: use of abandoned lands as constructive lands, Lcprgab_4: use of abandoned lands as urban open spaces, Lcprgab_6: use of abandoned lands as forests/woods, Lcprgab_7: use of abandoned lands for agriculture.

Table 5- 2 Rotated component matrix of factors analysis

Rotated Component Matrix							
	Factors						
	1	2	3	4	5	6	7
	Rural character-istics	Urbaniz-ation	Abandon-ment	Natural environ-ment	Richness and diversity of LUCC patches	Aggregation degree of LUCC	Conversions to arable lands
Zscore(PD)	-0.038	0.172	0.027	0.013	**0.841**	0.063	0.084
Zscore(LPI)	-0.076	0.242	0.093	-0.085	0.221	**0.811**	0.082
Zscore(SHDI)	0.409	0.095	0.216	0.208	**0.589**	-0.287	0.04
Zscore(AI)	-0.017	0.172	0.124	0.129	-0.313	**0.674**	0.035
Zscore(Lcprg_1)	0.463	0.104	0.023	**0.544**	-0.175	0.007	0.262
Zscore(Lcprg_2)	0.236	-0.105	-0.066	0.088	0.092	0.350	**0.609**
Zscore(Lcprg_3)	-0.066	**0.892**	0.055	-0.026	0.111	0.109	-0.057
Zscore(Lcprg_4)	-0.091	**0.854**	0.048	0.040	0.071	0.228	-0.013
Zscore(Lcprg_5)	0.014	0.372	**0.633**	0.359	0.113	0.007	0.016
Zscore(Lcprg_6)	-0.048	0.126	0.253	**0.654**	0.102	-0.040	0.167
Zscore(Lcprg_7)	0.009	-0.080	**0.665**	-0.004	0.012	0.054	0.082
Zscore(Lcprg_8)	-0.039	-0.033	**0.771**	0.022	0.032	0.072	-0.052
Zscore(Lcprg_9)	-0.100	-0.017	0.020	-0.013	0.035	-0.036	**0.699**
Zscore(Lcprg_10)	0.166	0.344	**0.581**	-0.041	0.003	0.028	-0.072
Zscore(Ldstapr_1)	-0.031	-0.189	-0.128	**0.828**	0.074	0.074	-0.215
Zscore(Ldstapr_345)	**0.865**	-0.169	0.042	-0.311	-0.010	-0.157	0.011
Zscore(Ldstapr_6)	**-0.530**	-0.117	0.376	0.048	0.095	-0.036	0.005
Zscore(Ldstapr_78)	**-0.843**	0.114	-0.111	-0.236	-0.259	-0.093	0.103
Zscore(P10_POP)	**-0.673**	0.320	-0.058	-0.148	-0.406	-0.154	0.143
Zscore(P10_FAR)	**0.659**	0.133	0.120	0.021	-0.212	-0.275	0.379

* PD: Patch Density. LPI: Largest Patch Index. AI: Aggregation Index. SHDI: Shannon's diversity index. Lcprg_1~Lcprg_10 are the ten principal land use changes in Ile-de-France, see Table 5-1 for description. Ldstapr_1, Ldstapr_345, Ldstapr_6, and Ldstapr_78 are percentage of municipal area composed by stable forests, stable agricultural lands (including arable lands, meadows and fruits), stable water area and stable urban area (including urban open spaces and urban building/infrastructures) through the period 1982-2012, respectively. P10_POP and P10_FAR are the population and number of farmers in the municipality in 2010, respectively.

2. Classification of municipalities and the different situations of abandonment

2.1. Naming the factors

The factor analysis has extracted 7 factors from 20 independent variables describing the characteristics of the municipalities in land use change, stable land use composition, population and number of farmers. The meaning of the factors can be explained according to the rotated component matrix (Table 5-2).

The first factor is highly positively related with the proportion of stable farmlands and number of professional farmers, but highly negatively related with the proportion of urban area and population, as well as water area. These are characteristics of a rural municipality with stable, important agricultural activities.

The second factor is highly positively related with area of urbanization (Lcprg_3 and Lcprg_4).

The third factor is highly related with the area of abandonment (Lcprg_5 and Lcprg_10) and the area of flows to agricultural lands (Lcprg_7) and water area (Lcprg_8). Because the trajectories towards new agricultural lands (luct_23, luct_93) and water areas (luct_36, luct_96) have close relations with abandoned lands, and they were marginal compared to the area of abandonment, the third factor can be considered as being dominated by abandonment.

The fourth factor is highly related with the proportion of stable forests/woods, area of the flows to new forests/woods, and area of conversions from arable lands to meadows/fruits. Thus, the fourth factor has the information about the natural environment. The fifth and the sixth factor are about the spatial pattern of land use changes.

The fifth factor tells about the richness and diversity of land use change patches, and the sixth about the aggregation degree. The seventh factor is mainly about the conversions to arable lands from meadows/fruits or from urban open spaces.

2.2. Results of the classification

The 7-cluster solution is the best for the classification of municipalities. It identifies 4 groups of municipalities and contains other 3 clusters of exceptions, i.e. municipalities with very particular characteristics. Fig. 5-4 shows the results of classification and Table 5-3 shows the cluster center of each group.

(1). Clusters of exceptions

Cluster 1 contains only one case, Marolles-sur-Seine (77), which has an extraordinary value on Factor 3 because of huge sand quarries. Cluster 4 has high values on Factor 6 and Factor 7 and contains 3 municipalities: Auteuil (78) and Etréchy (91) had a big patch convert to arable lands from prairies, and Guibeville (91) had a big patch convert to arable lands from fruit lands.

Cluster 5 contains 5 municipalities. Its high value on Factor 7 suggests important conversions towards arable lands from urban open spaces, but in fact, these conversions in the 5 municipalities were all marked on grass lands in airports, which probably resulted from misinterpretation. Mouroux (77) and Pommeuse (77) are concerned by the aerodrome of Coulommiers-Voisins, Athis-Mons (91) and Villeneuve-le-Roi (94) by the airport Orly, and Vélizy-Villacoublay (78) by another air base.

(2). Valid clusters

The Cluster 2, 3, 6, and 7 contain respectively 934, 171, 44 and 83 municipalities.

The Cluster 2 groups the municipalities in the rural fringe of the region, and agricultural activities have important place. They have the highest value on Factor 1 (rural characteristics) among the four groups, and relatively low value on Factor 2 (urbanization) and Factor 3 (abandonment) and intermediate level on other factors. So the processes of urbanization and land abandonment are not dramatic.

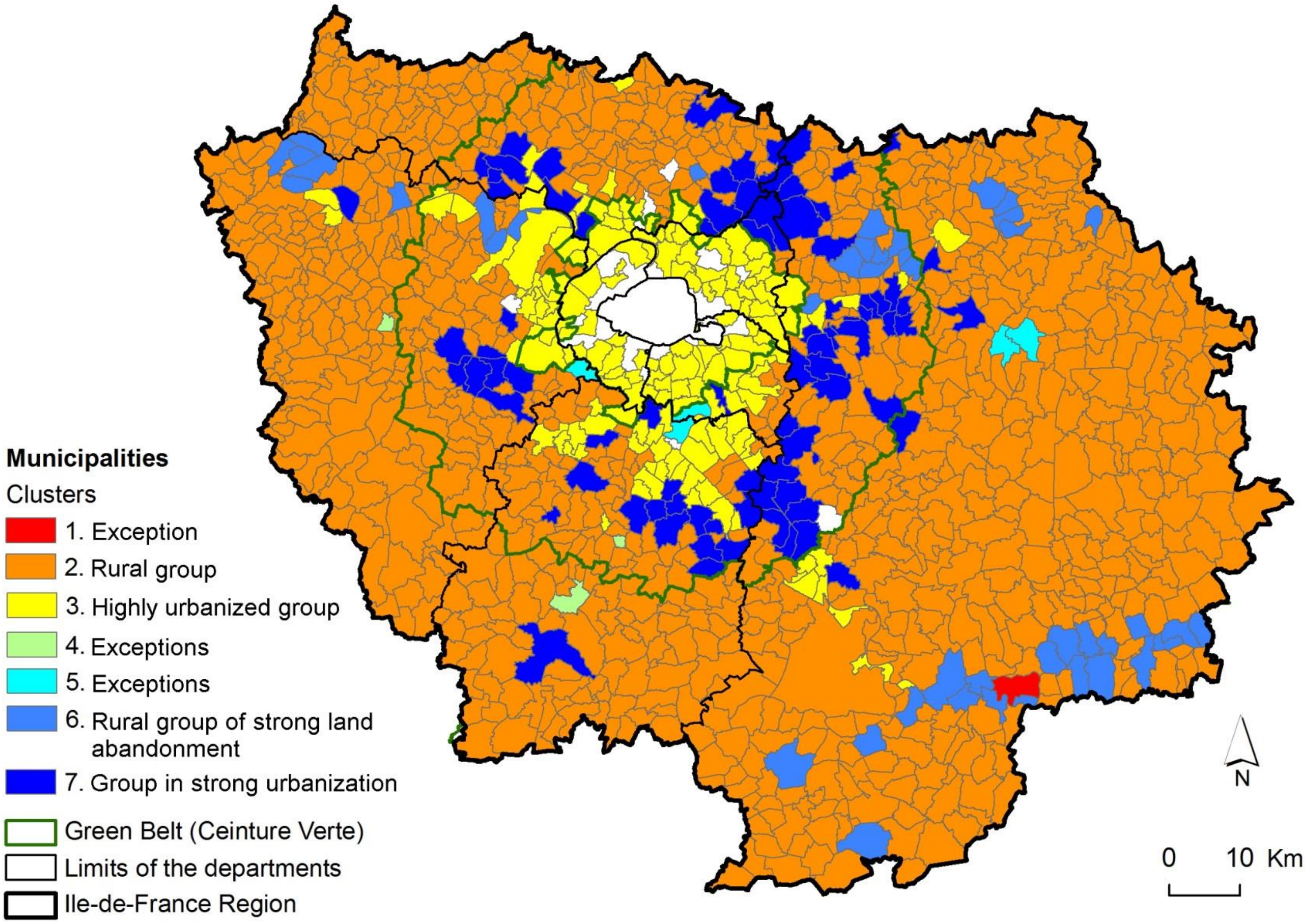


Fig. 5- 4. Municipalities classified into 7clusters

The Cluster 3 groups highly urbanized municipalities which are located closely surrounding Paris city or dispersed in the valley of Seine and Marne, e.g. Mante-la-Jolie (78), Meaux (77) and Melun (77). They have the lowest value on Factor 1 (rural characteristics), Factor 4 (natural environment) and Factor 5 (richness and biodiversity of land use change patches). So these highly urbanized municipalities had a low intensity of land use changes.

The Cluster 6 groups municipalities that are located in the rural fringe but are different from those in Cluster 2 because of significant land abandonment. They are located principally in the benches of Seine (e.g. at Moisson (78), and at Triel (78)) and Marne (e.g. at Jablines (77), at Isles-les-Meldeuse (77) and at Luzancy (77)), and in the Valley of Bassée, the upstream of Seine. This group of municipalities has the highest value on Factor 3 (abandonment) and Factor 4 (natural environment). So Cluster 6 probably revealed a particular situation of land abandonment linked to natural factors.

Table 5- 3 Final cluster centers

	cluster1	**cluster 2**	**cluster 3**	cluster 4	cluster 5	**cluster 6**	**cluster 7**
Number of municipalities	1	934	171	3	5	44	83
			Final Cluster Centers				
Factor 1	-1.083	**0.362**	**-1.757**	0.395	-2.072	-0.371	-0.134
Factor 2	-2.971	-0.213	-0.018	-1.350	-0.437	-0.242	**2.671**
Factor 3	**21.352**	-0.138	-0.194	-0.751	0.045	**3.181**	0.029
Factor 4	-0.908	0.096	**-0.525**	-1.118	-0.330	**0.395**	-0.141
Factor 5	-1.132	0.139	**-1.040**	2.149	0.343	0.382	0.294
Factor 6	2.337	-0.064	-0.276	**9.393**	-0.335	0.155	**0.861**
Factor 7	1.027	-0.036	0.079	**5.937**	**8.725**	-0.320	-0.337

Finally, the Cluster 7 groups the municipalities near the New Towns, new urban sub-centers implanted by the government: Cergy-Pontoise located in Yvelines and Val-d'Oise, Saint-Quentin en Yvelines located in Yvelines, Evry in Essonne, Sénart in Essonne and Seine-et-Marne, and Marne-la-Vallée in Seine-et-Marne. The zone of the airport CDG is also in this category, including a dozen of municipalities located in Seine-et-Marne, Seine-Saint-Denis and Val-d'Oise. These municipalities have the highest value on Factor 2 (urbanization) and Factor 6 (aggregation degree of land use change patches), which suggests a compact pattern of urbanization.

The four groups include some special cases. For example, the three municipalities Le Mesnil-le-Roi (78), Montesson (78) and Carrière-sur-Seine (78) in Cluster 1 indicate a residual agricultural zone enclosed by urban agglomeration. The Cluster 3 includes also several municipalities dispersed in the rural area which have a high proportion of urbanised area because of their small size, e.g. Persan (95), Arpajon (91), Avon (77), Thomery (77), Saint-Mammès (77), and Esbly (77). Le Plessis-Gassot (95) in Cluster 6 is not located in a river bench like the others, but it has one of the two biggest landfill sites of Ile-de-France.

The Cluster 7 includes different kinds of special cases: (i) residual zones in the highly urbanised inner urban area where the process of urbanization is in progress, e.g. Valenton (94), Wissous (91), and Cormeilles-en-Parisis (95); (ii) dispersed hotpots in the rural area undergoing relatively strong urbanisation, e.g. Courson-Monteloup (91), Etampes (91), Châtres (77), Tournan-en-Brie (77), Saint-Mard (77), Saint-Pathus (77) and Luzarches (95), or having created golf courses, e.g. Crecy-la-Chapelle (77); (iii) frontiers between highly urbanised area and the rural area, e.g. Limay (78), Noisy-le-Roi (78), Villebon-sur-Yvette (91), Vaux-le-Penil (77), and Mareuil-lès-Meaux (77).

2.3. Differences among groups and test of significance

In order to identify the differences among the four groups, this section compares their means and standard deviations on 27 original indicators (including the 20 indicators used for clustering analysis, the municipal area and 6 indicators about the conversions of abandoned lands) as shown in Table 5-4 and presents the results of pairwise Mann-Whitney Tests in Table 5-5-1 and Table 5-5-2. Most of the indicators reject the null hypothesis of Mann-Whitney Test, so the differences among the four groups are significant. The classification of municipalities is effective.

Table 5- 4 Means and Standard deviations of the indicators for the four groups of municipalities

	Cluster Mean				Std. Deviation			
	Cluster 2	Cluster 3	Cluster 6	Cluster 7	Cluster 2	Cluster 3	Cluster 6	Cluster 7
PD	8.8	4.4	9.9	10.9	5.3	3.5	2.8	4.5
LPI	1.9	1.6	4.0	**7.2**	2.0	1.7	2.8	6.2
SHDI	1.4	0.8	**1.6**	1.3	0.3	0.4	0.2	0.2
AI	70.4	71.2	74.6	**77.6**	7.6	13.0	6.5	5.5
Lcprg_1	29.8	2.3	24.3	20.9	29.2	6.0	20.3	25.5
Lcprg_2	10.0	**0.5**	4.1	3.8	17.0	3.3	5.7	8.9
Lcprg_3	9.5	11.3	11.5	95.3	11.6	14.4	12.3	53.4
Lcprg_4	11.4	15.3	16.8	96.1	13.3	18.1	16.3	57.2
Lcprg_5	10.4	**4.6**	57.8	30.0	12.3	10.5	36.2	29.7
Lcprg_6	4.5	1.9	11.8	6.3	6.0	5.3	16.2	8.1
Lcprg_7	1.2	**0.1**	6.0	1.5	2.3	0.4	11.7	2.7
Lcprg_8	0.3	0.2	25.8	2.5	1.5	1.0	27.6	3.4
Lcprg_9	0.4	0.2	0.4	0.4	1.1	0.9	0.6	1.2
Lcprg_10	2.0	0.2	20.3	8.2	5.3	1.4	27.0	13.3
Ldstapr_1	0.22	0.10	0.18	0.14	0.18	0.15	0.14	0.12
Ldstapr_345	0.53	0.02	0.37	0.27	0.25	0.04	0.19	0.18
Ldstapr_6	0.01	0.03	0.06	0.01	0.02	0.05	0.05	0.02
Ldstapr_78	0.10	0.67	0.10	0.21	0.10	0.16	0.09	0.13
P10_POP	1952	29632	2821	12383	3041	21611	4705	11262
P10_FAR	5.6	0.7	4.0	3.6	5.4	1.3	4.3	4.4
Area_Com	987.1	640.8	1116.0	1107.3	830.2	497.2	614.1	645.7
Lcprgab_3	1.8	4.7	3.3	11.9	3.2	6.4	4.5	15.8
Lcprgab_4	2.1	6.0	4.7	15.4	3.3	10.6	5.3	15.7
Lcprgab_5	10.4	4.6	57.8	30.0	12.3	10.5	36.2	29.7
Lcprgab_6	3.0	1.7	9.7	4.4	4.6	5.1	14.3	6.3
Lcprgab_7	1.1	0.1	5.0	1.4	2.2	0.4	10.1	2.6
Lcprgab_10	0.8	0.1	5.2	2.9	2.0	0.4	8.4	8.1

*Area_Com: area of the municipality. For the signification of the other indicators, see notes of Table 5-2.

Table 5- 5-1 Mann-Whitney tests on differences between each pair of groups

	Cluster 2-Cluster 3				**Cluster 2- Cluster 6**				**Cluster 2- Cluster 7**			
	U	**Z**	**Sig.**	**r**	**U**	**Z**	**Sig.**	**r**	**U**	**Z**	**Sig.**	**r**
PD	34672	-11.777	0.000	0.57	14242	-3.444	0.001	0.31	26601	-4.742	0.000	0.31
LPI	64764	-3.934	0.000	0.19	8294	-6.692	0.000	0.60	7451	-12.209	0.000	0.81
SHDI	20527.5	-15.464	0.000	0.74	12444	-4.426	0.000	0.39	28601.5	-3.962	0.000	0.26
AI	73880	-1.558	**0.119**	0.07	13698	-3.741	0.000	0.33	17021	-8.477	0.000	0.56
Lcprg_1	9838.5	-18.262	0.000	0.88	19335	-0.662	**0.508**	0.06	29093.5	-3.770	0.000	0.25
Lcprg_2	26022.5	-14.331	0.000	0.67	16607	-2.170	0.030	0.19	25953.5	-5.044	0.000	0.33
Lcprg_3	76642	-0.838	**0.402**	0.04	18997.5	-0.847	**0.397**	0.08	1123	-14.677	0.000	0.97
Lcprg_4	76372	-0.908	**0.364**	0.04	15395	-2.814	0.005	0.25	1382.5	-14.576	0.000	0.96
Lcprg_5	35355	-11.603	0.000	0.56	3263.5	-9.440	0.000	0.84	19444	-7.533	0.000	0.50
Lcprg_6	38073	-10.921	0.000	0.52	12890	-4.185	0.000	0.37	36728	-0.793	**0.428**	0.05
Lcprg_7	28320	-13.752	0.000	0.65	10506	-5.531	0.000	0.49	37949.5	-0.320	**0.749**	0.02
Lcprg_8	66858	-4.348	0.000	0.16	2981	-11.567	0.000	0.85	12600	-12.109	0.000	0.67
Lcprg_9	59574.5	-5.866	0.000	0.25	18498.5	-1.214	**0.225**	0.10	35848	-1.237	**0.216**	0.08
Lcprg_10	39500.5	-11.130	0.000	0.51	7072	-7.579	0.000	0.66	20815.5	-7.198	0.000	0.46
Ldstapr_1	40038.5	-10.379	0.000	0.50	18256.5	-1.251	**0.211**	0.11	26973.5	-4.596	0.000	0.30
Ldstapr_345	2569.5	-20.147	0.000	0.97	12657.5	-4.309	0.000	0.38	16307	-8.756	0.000	0.58
Ldstapr_6	48066.5	-8.339	0.000	0.40	3624	-9.300	0.000	0.82	29235.5	-3.738	0.000	0.25
Ldstapr_78	753	-20.618	0.000	0.99	19564	-0.537	**0.591**	0.05	18133	-8.044	0.000	0.53
P10_POP	3553	-19.888	0.000	0.96	19176.5	-0.749	**0.454**	0.07	9516.5	-11.404	0.000	0.75
P10_FAR	22246.5	-15.289	0.000	0.72	16659.5	-2.158	0.031	0.19	29077.5	-3.840	0.000	0.25
Area_Com	50137	-7.746	0.000	0.37	16745	-2.077	0.038	0.19	31908	-6.062	0.000	0.18
Lcprgab_3	60126	-5.169	0.000	0.25	17126.5	-1.879	0.060	0.17	13816	-9.769	0.000	0.64
Lcprgab_4	65934	-3.636	0.000	0.17	13129	-4.058	0.000	0.36	6691.5	-12.521	0.000	0.83
Lcprgab_5	35355	-11.603	0.000	0.56	3263.5	-9.440	0.000	0.84	19444	-7.533	0.000	0.50
Lcprgab_6	45383	-9.049	0.000	0.43	12082.5	-4.637	0.000	0.41	37056.5	-0.667	**0.505**	0.04
Lcprgab_7	28935.5	-13.604	0.000	0.64	12099	-4.658	0.000	0.41	37435.5	-0.523	**0.601**	0.03
Lcprgab_10	46856.5	-9.703	0.000	0.41	12445.5	-4.782	0.000	0.39	31114	-3.223	0.001	0.20

*Significance (2-tailed); r: effective size. Area_Com: area of the municipality. Lcprgab_3~Lcprgab_10 are the area of conversions of abandoned lands corresponding to the ten principal categories of land use change in Table 5-1. For the signification of the other indicators, see notes of Table 5-2.

Table 5-5-2 Mann-Whitney tests on differences between each pair of groups (Cont.)

	Cluster 3- Cluster 6				Cluster 3- Cluster 7				Cluster 6- Cluster 7			
	U	**Z**	**Sig.**	**r**	**U**	**Z**	**Sig.**	**r**	**U**	**Z**	**Sig.**	**r**
PD	915	-7.736	0.000	0.76	1793.5	-9.656	0.000	0.75	1680	-0.740	**0.459**	0.08
LPI	1269	-6.774	0.000	0.66	1205	-10.728	0.000	0.83	1056	-3.901	0.000	0.42
SHDI	320	-9.355	0.000	0.91	2549.5	-8.281	0.000	0.64	568	-6.374	0.000	0.69
AI	3048	-1.940	**0.052**	0.19	4319	-5.058	0.000	0.39	1331.5	-2.505	0.012	0.27
Lcprg_1	470	-9.612	0.000	0.88	1782.5	-10.173	0.000	0.75	1422.5	-2.045	0.041	0.22
Lcprg_2	1612.5	-7.776	0.000	0.57	4258.5	-6.739	0.000	0.40	1518	-1.632	**0.103**	0.17
Lcprg_3	3349.5	-1.121	**0.262**	0.11	314.5	-12.350	0.000	0.96	71	-8.892	0.000	0.96
Lcprg_4	3164.5	-1.624	**0.104**	0.16	572	-11.881	0.000	0.92	129	-8.598	0.000	0.93
Lcprg_5	279.5	-9.679	0.000	0.93	1635	-10.092	0.000	0.77	910	-4.641	0.000	0.50
Lcprg_6	1147.5	-7.433	0.000	0.69	3363	-7.023	0.000	0.53	1320.5	-2.563	0.010	0.28
Lcprg_7	405.5	-11.405	0.000	0.89	3098	-9.032	0.000	0.56	994.5	-4.249	0.000	0.46
Lcprg_8	445.5	-11.332	0.000	0.88	1768	-11.350	0.000	0.75	650	-5.968	0.000	0.64
Lcprg_9	2535	-4.242	0.000	0.33	5843.5	-2.928	0.003	0.18	1534.5	-1.634	**0.102**	0.16
Lcprg_10	478	-11.351	0.000	0.87	1567	-11.859	0.000	0.78	1268.5	-2.829	0.005	0.31
Ldstapr_1	2193.5	-4.278	0.000	0.42	4936.5	-3.942	0.000	0.30	1463.5	-1.837	**0.066**	0.20
Ldstapr_345	271.5	-9.638	0.000	0.93	842	-11.505	0.000	0.88	1268	-2.827	0.005	0.31
Ldstapr_6	1835	-5.250	0.000	0.51	5289.5	-3.303	0.001	0.25	388	-7.295	0.000	0.79
Ldstapr_78	25	-10.155	0.000	0.99	248	-12.470	0.000	0.97	780	-5.300	0.000	0.57
P10_POP	293	-9.426	0.000	0.92	3160	-7.168	0.000	0.55	577	-6.328	0.000	0.68
P10_FAR	1651.5	-6.226	0.000	0.56	3165	-7.665	0.000	0.55	1741	-0.448	**0.654**	0.05
Area_Com	1531	-6.062	0.000	0.59	3257	-6.991	0.000	0.54	1800	-0.132	**0.895**	0.01
Lcprgab_3	3420.5	-0.931	**0.352**	0.09	4412.5	-4.893	0.000	0.38	961	-4.384	0.000	0.47
Lcprgab_4	3425.5	-0.918	**0.359**	0.09	3145.5	-7.207	0.000	0.56	768	-5.361	0.000	0.58
Lcprgab_5	279.5	-9.679	0.000	0.93	1635	-10.092	0.000	0.77	910	-4.641	0.000	0.50
Lcprgab_6	1323	-7.013	0.000	0.65	4286	-5.396	0.000	0.40	1267.5	-2.845	0.004	0.31
Lcprgab_7	604.5	-10.851	0.000	0.84	3198.5	-8.845	0.000	0.55	1088	-3.781	0.000	0.40
Lcprgab_10	1236.5	-10.110	0.000	0.67	3220.5	-9.600	0.000	0.55	1456	-1.924	**0.054**	0.20

In order to characterize the differences between each pair of groups, Table 5-6 formulates a matrix that has selected the indicators on which two groups have no significant difference (Sig. > 0.05) and the indicators that they have the most important difference (effect size > 0.8).

The highly urbanized municipalities in Cluster 3 don't have significant difference with the rural municipalities in Cluster 2 in terms of land use changes. They are differentiated in terms of the percentage of land comprised by stable urban area or agricultural lands, population, and changes from arable lands to meadows/fruits.

Cluster 6 is similar to Cluster 2, and has remarkable rural characteristics, namely, relatively high level in land use changes from arable lands to meadows/fruits, percentage of stable forests, but less urban area and a low population. They are significantly different in terms of land abandonment and land use changes concerning water area, for which, Cluster 6 is more visible.

Cluster 6 is not distinct with Cluster 3 as for the level of urbanization, but the two groups have big differences in multiple aspects: the diversity of land use changes, the magnitude of abandonment, the reuse of abandoned lands for cultivation or water area, percentage of stable agricultural lands and percentage of stable urban area, as well as population.

Cluster 7 concerns municipalities in rapid peri-urbanization. They have common characteristics with Cluster 2 for an intermediate level of reforestation and re-cultivation, but the Cluster 7 has distinctly big patches of urbanization suggested by the high level of Largest Patch Index (LPI) and area of urbanization.

Table 5- 6 Matrix of the differences and similarities among groups

	Cluster 2	Cluster 3	Cluster 6	Cluster 7	
Cluster 2		Lcprg_1, Ldstapr_345, Ldstapr_78, P10_POP	Lcprg_5, Lcprg_8, Ldstapr_6, Lcprgab_5	LPI, Lcprg_3, Lcprg_4, Lcprgab_4	**Indicators of differences (Mann-Whitney Test r > 0.8)**
Cluster 3	AI, Lcprg_3, Lcprg_4		SHDI, Lcprg_1, Lcprg_5, Lcprg_7, Lcprg_8, Lcprg_10, Ldstapr_345, Ldstapr_78, P10_POP, Lcprgab_5, Lcprgab_7	LPI, Lcprg_3, Lcprg_4, Ldstapr_345, Ldstapr_78	
Cluster 6	Lcprg_1, Lcprg_3, Lcprg_9, Ldstapr_1, Ldstapr_78, P10_POP	AI, Lcprg_3, Lcprg_4, Lcprgab_3, Lcprgab_4		Lcprg_3, Lcprg_4	
Cluster 7	Lcprg_6, Lcprg_7, Lcprg_9, Lcprgab_6, Lcprgab_7	-	PD, Lcprg_2, Lcprg_9, Ldstapr_1, P10_FAR, Area_Com, Lcprgab_10		
	Indicators of similarities (Mann-Whitney Test Sig. > 0.05)				

No indicators suggest similarities between Cluster 7 and Cluster 3. The two groups are significantly different in terms of LPI, area of urbanization and percentage of stable agricultural lands and stable urban area. Therefore municipalities in Cluster 7 are still very different from the highly urbanized area.

Cluster 6 and Cluster 7 are similar in several aspects: a high level of land use change patch density, an intermediate percentage of stable forests and number of farmers, and a relatively larger municipal area. The characteristics that distinguish the two groups are the magnitude of urbanization to constructive lands and urban open space.

Thus, Cluster 3 as already highly urbanized area is the most distinct from the other three groups which are marked by a certain degree of rural characteristics. Cluster 3 and Cluster 2 both have more stable land use pattern while the Cluster 6 and Cluster 7 have the most dynamic land use changes. Cluster 7 is most dominated by urbanization, while Cluster 6 by other factors rather than urbanization. The four groups of municipalities are in different situations of land use and thus may be faced with particular problems in the management of abandoned lands.

As for the magnitude of abandonment, Cluster 6 had the highest average area of abandoned farmlands as 57.8 ha, followed by Cluster 7 as 30 ha. Cluster 3 had the lowest level as 4.6 ha. Then, as for the reuse of abandoned farmlands, municipalities in Cluster 6 used 14.7 ha on average for agriculture or forests, while Cluster 3 used only 1.8 ha on average. Municipalities in Cluster 7 used 27.3 ha of abandoned farmlands on average for urban use while those in Cluster 2 used only 3.9 ha on average.

Table 5-7 is a summary for the situations of abandonment in the four groups of municipalities according to the data in Table 5-4.

Table 5- 7 A summary of abandonment in the four groups of municipalities classified

	Cluster 2	Cluster 3	Cluster 6	Cluster 7
Average net abandonment (ha)	2.2	-8.0	35.1	-3.2
Number of municipalities	934	171	44	83
Total area of municipalities (ha)	921927	109574	49104	91906
Total net abandonment (ha)	2096.9	-1371.5	1545.0	-261.7
Proportion of using abandoned lands in urban construction	0.19	0.42	0.28	0.12
Proportion of using abandoned lands in new urban open spaces	0.19	0.39	0.28	0.16

The net abandonment was 2.2 ha, -8.0 ha, 35.1 ha, and -3.2 ha on average in the municipality of Cluster 2, Cluster 3, Cluster 6 and Cluster 7, respectively. Cluster 3 had little new abandonment and highly relied on abandoned lands for urbanization. Abandoned lands counted 42% of the lands used for construction and 39% for creation of urban open spaces. Cluster 7 had important area abandoned and also reused especially for urbanization in the study period, but abandoned lands counted only 12% and 16% of the lands used for construction and urban open spaces, respectively. Cluster 2 and Cluster 6 were sources of net increase of abandoned lands in the region, because urbanization was weak, and return of abandoned lands to agriculture or forests was also very marginal comparing to the magnitude of abandonment.

After having considered the number of municipalities in each group, Cluster 2 turned out have the highest net increase of abandoned lands while Cluster 3 the highest net decrease of abandoned lands. At the regional level, the amount of abandonment exceeded the amount of abandoned lands reused for urbanization, forests and agriculture.

2.4. Different situations of abandoned lands among the four groups

This section tries to identify the particular situations of abandoned lands in each group of municipalities by referring to the Google Street view and administrative documents, e.g. Local Plans of Urbanization (PLU). The fields of abandoned lands were also compared with the Graphical Land Parcel Registration (RPG) declared by farmers for allocation of European subsidies, principally in the frame of Common Agricultural Policy.

Fig. 5-5 presents four maps that separately display the area of abandonment at municipal level in each group. These maps help to locate municipalities with important area of abandoned lands. It suggests that Cluster 2 has two types of municipalities that are highly concerned by land abandonment:

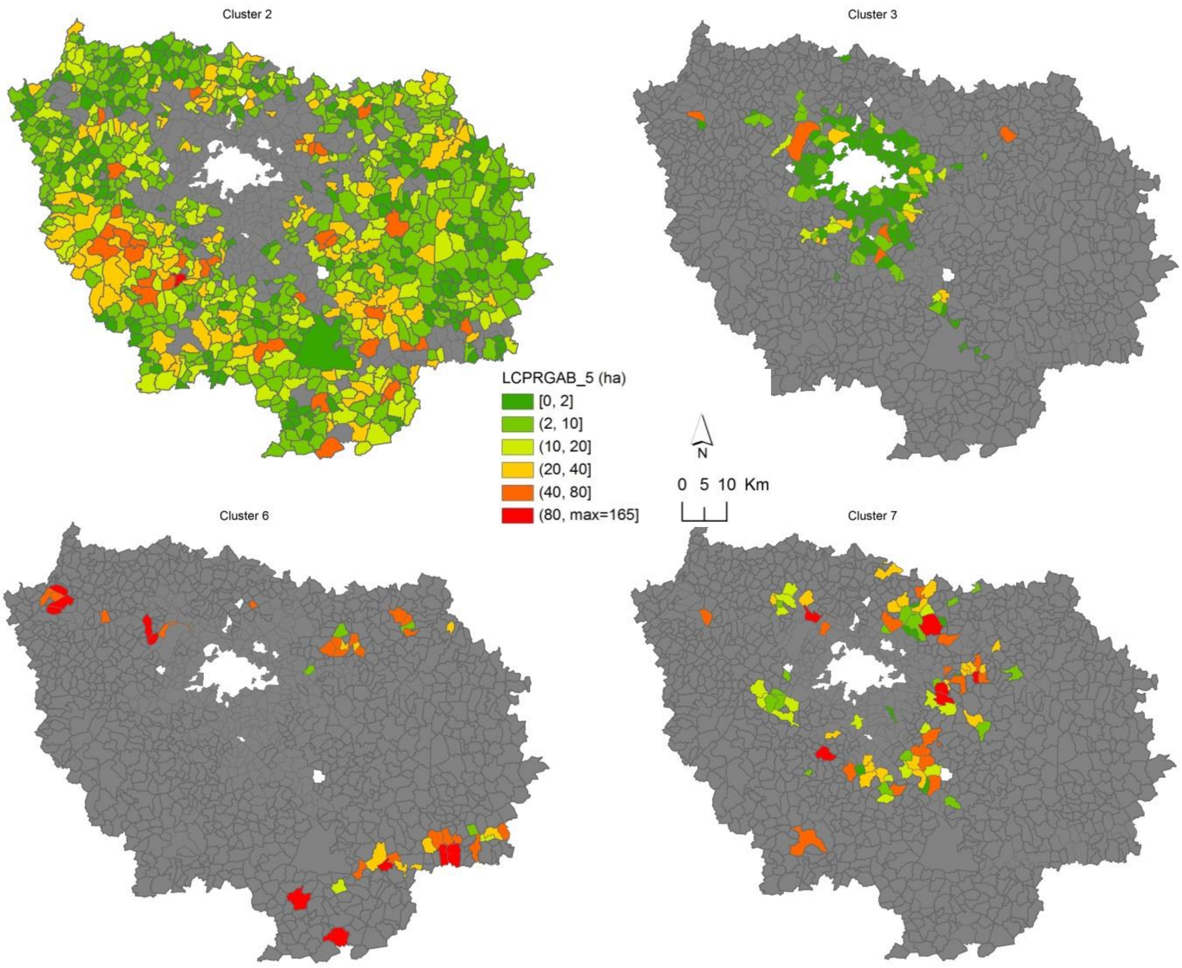


Fig. 5- 5. Area of abandonment at municipal level in different groups

The first type includes those individually dispersed and surrounded by municipalities with weak abandonment. The second type forms some concentration zones where the adjacent municipalities all have significant area of abandonment. There are three such zones, which correspond to three Agricultural Regions (Région Agricole), namely, Yvelines and Hurepoix in the west of the Ile-de-France and Brie Humide in the south-east of the region. Important land abandonment in an individually dispersed municipality often results from particular reasons linked to the municipality itself; while in the concentration zone, those municipalities possibly share some common factors that encourage land abandonment.

Fig. 5-5 also suggests that among the New Towns of the cluster 7 in strong peri-urbanization, the Ville Nouvelle Saint-Quentin-en-Yvelines are not touched strongly by the phenomenon of land abandonment, while the Ville Nouvelle Marne-la-Vallée is totally opposite.

2.4.1. Cluster 2: municipalities with strong rural characteristics

The most important land abandonment may be concluded into three categories in terms of spatial location:

(1). Land abandonment following implantation of projects or infrastructures

Lands were destroyed and became unsuitable for agricultural exploitation. These cases could be gypsum mining (e.g. Le Pin (77) and Villeparisis (77)), sand mining (e.g. Saint-Maurice-Montcouronne (91)), industrial activities (e.g. Gargenville (78)), deforestation for passing high-voltage cables (e.g. Vernou-la-Celle-sur-Seine (77), Coubert (77) and Grisy-Suisnes (77)), and construction of highways (e.g. Briis-sous-Forges (91)). Fig. 5-6 presents some photos of this type found from Google Street view and website.

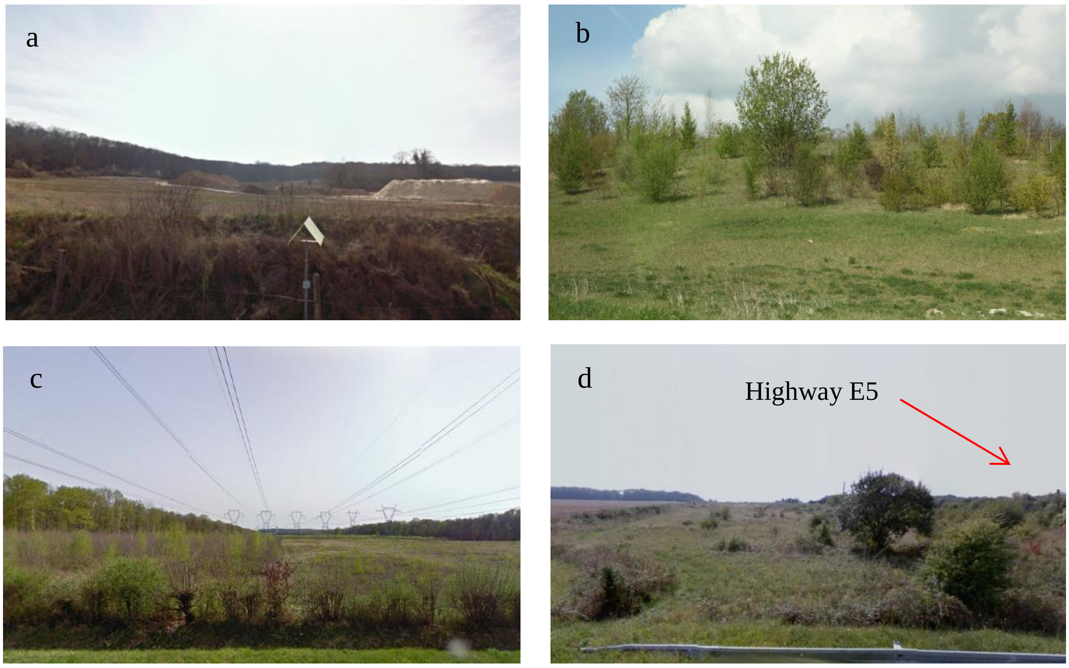


Fig. 5- 6. Abandoned lands of the first category in Cluster 2. a. sand mining in Saint-Maurice-Montcouronne (91), b. revegetation after gypsum mining in Le Pin (77) and VilleParisis (77), c. deforestation for passing high-voltage cables in Vernou-la-Celle-sur-Seine (77), d. abandoned lands along the highway E5 in Briis-sous-Forges (91). Source: Google Street view and website.

(2). Land abandonment close to urban area

The example of Saint-Pierre-lès-Nemours (77) represents one case of land abandonment close to urban area. As the map in Fig. 5-7a shows, its urban area is located between two vast forests. Urban area gradually reached forests and the residual agricultural lands in between were abandoned. Though some parcels were still declared in the RPG of 2010, obviously there was no agricultural activity on them and trees began to grow (Fig. 5-7b).

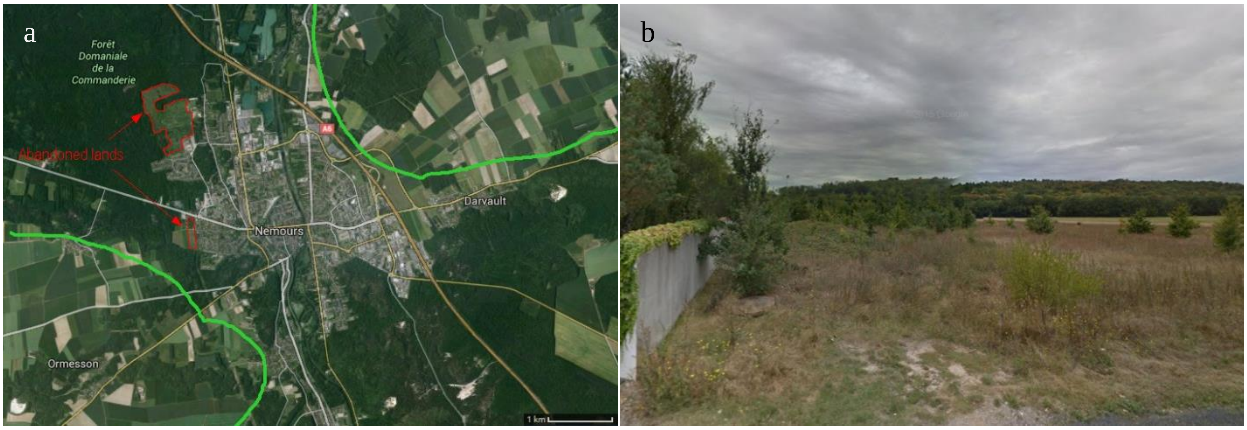


Fig. 5- 7. Abandoned lands in Saint-Pierre-lès-Nemours (77). Source: Google maps.

Another case is the abandonment of agricultural lands when progressively enclosed by urban areas, which usually happened in the municipalities at the frontier between Parisian agglomeration and its rural suburb (e.g. Méry-sur-Oise (95) and Linas (91)). Taking Linas as an example, a residual zone of agriculture was enclosed by residences, commercial centre and the highway La Francilienne (Fig. 5-8a). A big part of the agricultural lands were abandoned and a number of caravans settled down there (Fig. 5-8b).

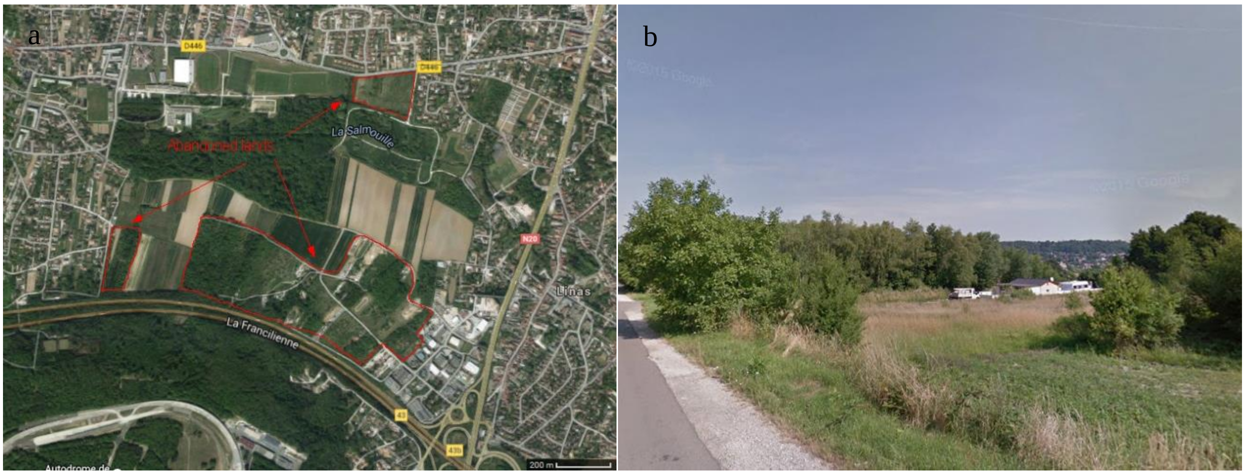


Fig. 5- 8. Abandoned lands in Linas (91). Source: Google maps.

(3). Land abandonment in natural environment

This type of abandonment happened principally on lands with poor agronomic quality but having high ecological value.

One case is abandonment in the frontier between forests and agricultural lands. The three concentration zones of land abandonment identified from Fig. 5-5 basically correspond to this situation. The municipalities in Yvelines, such as Auffargis, Cernay-la-Ville, La Celle-les-Bordes and Le-Perray-en-Yvelines are in the “fight” against forest expansion. These municipalities are located in the forests of Rambouillet, and attached to the PNR of Chevreuse. The habitants have a high willingness for environment protection and against urbanization. As Fig. 5-9a shows, abandoned agricultural lands are principally located in the adjacent area to forests and often not near urban area. These lands can quickly evolve towards wood lands and obstruct the landscape. That’s why the habitants expect regular management on abandoned farmlands just to maintain them as open spaces. Fig. 5-9b and 5-9c present some photos of abandoned lands in this area.

Another case is land abandonment in the valley. These abandoned farmlands may be declared as type II of ZNIEFF (Natural zone of ecological interest, fauna and flora). Type II of ZNIEFF are big areas with high ecological potential and are important for ecological and landscape cohesion. One example is the Valley of Rémarde in Saint-Maurice-Montcouronne (91).

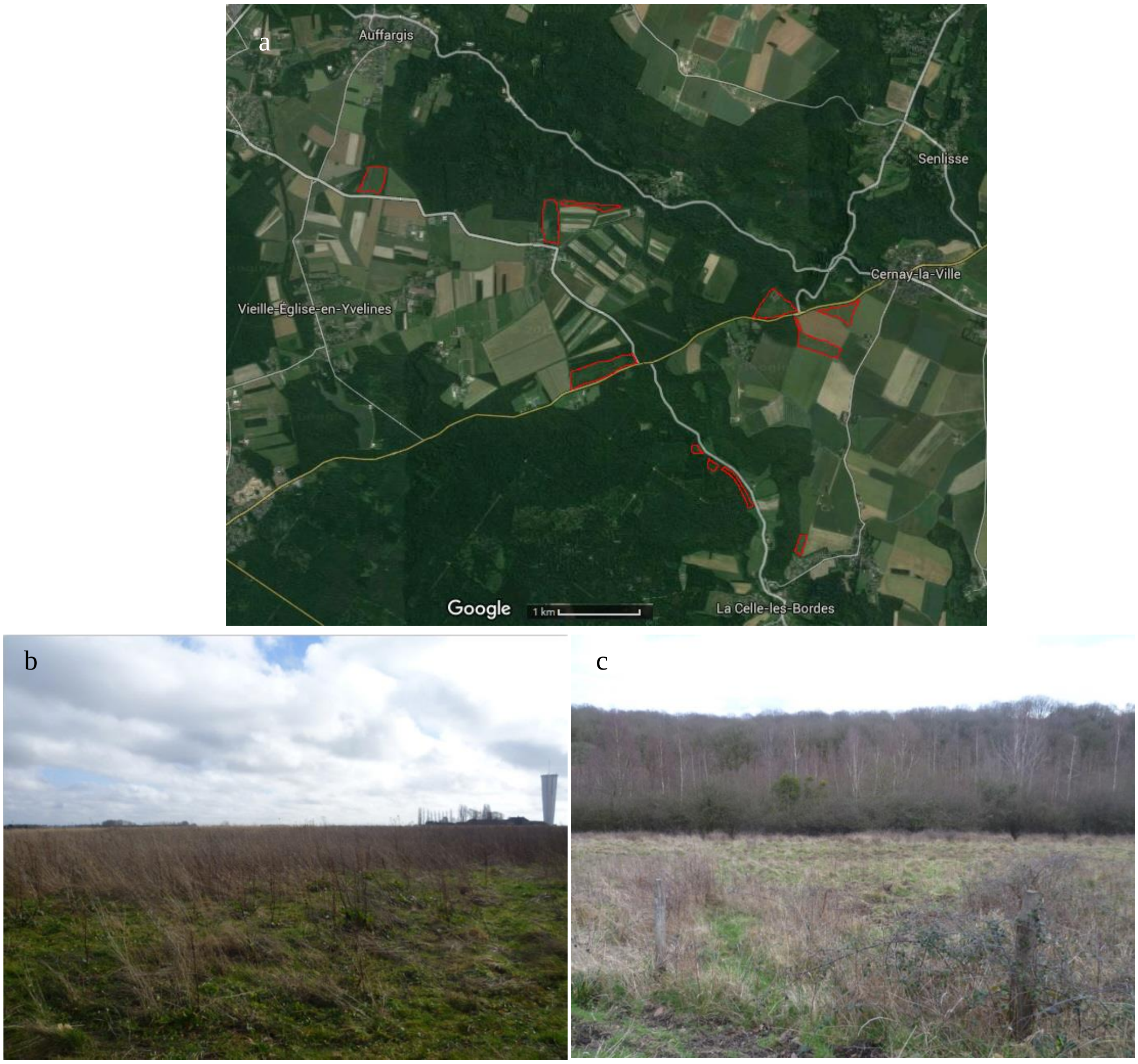


Fig. 5- 9. Distribution of abandoned lands in three adjacent municipalities in the PNR of Chevreuse (a. the municipalities are Auffargis, Cernay-la-Ville and La Celle-les-Bordes, all in Yvelines (78), b. an abandoned land in Cernay-la-Ville, c. an abandoned land in La Celle-les-Bordes. Source: field visit)

2.4.2. Cluster 3: highly urbanized municipalities

In the highly urbanized municipalities, there exist some residual zone of abandoned farmlands enclosed by urban area and infrastructure (e.g. railway, highway) or river. Ris-Orangis(91) is the most representative example. Vast areas of lands are left in the state of abandonment between the urban area and a number of transportation lines, namely, the RER, D31, D91, and N7 (Fig. 5-10a). There are no agricultural lands in the municipality except for three parcels declared in the RPG of 2010 in the category “Other types of fallow lands”.

Other municipalities the most concerned by abandoned lands are in the same situation, such as Vigneux-sur-Seine (91), Meaux (77), Mantes-la-Jolie (78), Vitry-sur-Seine (94), and commonly see that caravans settle down on these abandoned lands (Fig. 5-10b, 5-10c, 5-10d).

In some municipalities, one or several parcels are still cultivated in these residual zones, e.g. Vigneux-sur-Seine and Meaux. It is not certain if these lands will be abandoned in the future. Saint-Germain-en-Laye (78) is another case where abandonment of agricultural activities was due to an industrial project.

Fig. 5- 10. Abandoned lands in the highly urbanized municipalities. a. distribution of abandoned lands in Ris-Orangis (91), b. one of the abandoned lands in Ris-Orangis, c. an abandoned land in Meaux (77), d. an abandoned land in Mante-la-Jolie (78). Source: Google map.

2.4.3. Cluster 6: municipalities in strong land abandonment because of non-urban factors

Vast area of abandoned lands in the municipalities of Cluster 6 results from non-urban factors such as sand extraction, soil pollution and instability of wetlands for agricultural use.

(1). Sand extraction

The case of sand extraction has the best example in two adjacent benches of Seine including Moisson (78), Mousseaux-sur-Seine (78), Freneuse (78), Saint-Martin-la-Garenne (78), and Guernes (78). Fig. 5-11a shows a photo of such abandoned land in Guernes. It had poor vegetation after abandonment of sand extraction. But after a long time, this type of area can become rich in biodiversity. For example, the Regional Natural Reserve Boucle de Moisson (RNR203) was created in

2009 in a big area where the lands stayed fallow for 17 years after the stop of sand extraction. Fig. 5-11b shows one photo of this area nowadays. It has turned into a natural state.

Fig. 5- 11. Abandoned lands in the bench of Moisson. a. One abandoned land in Guernes (78), b. Regional Natural Reserve Boucle de Moisson (78). Sources: Google maps and NatureParif.

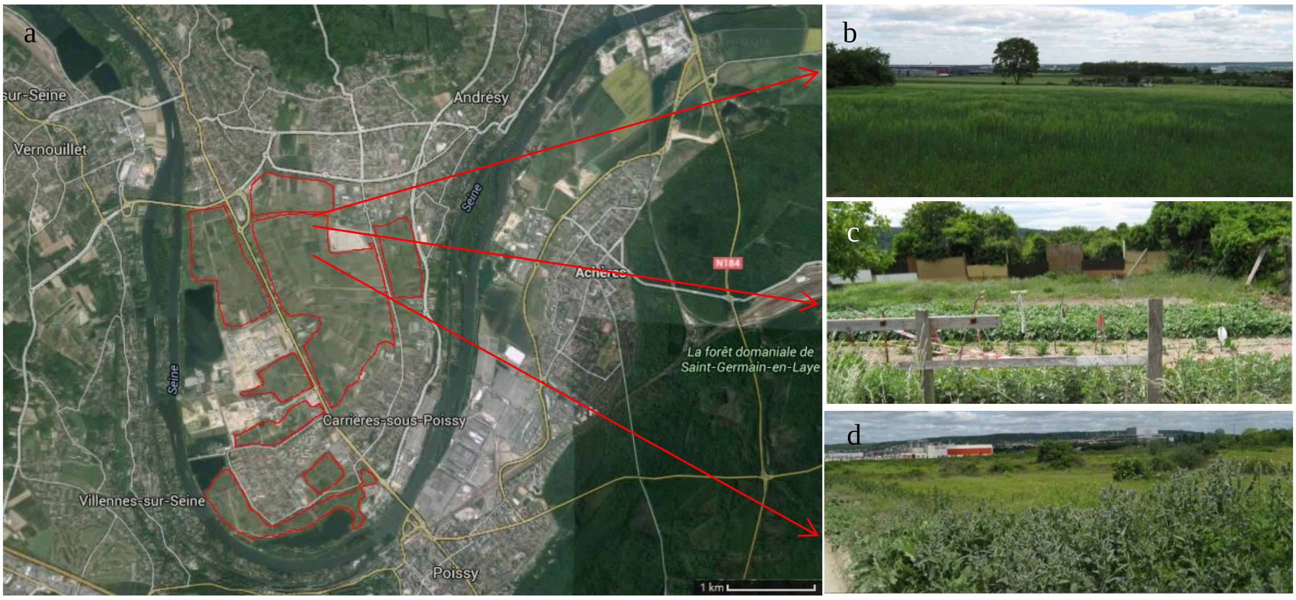


Fig. 5- 12. A zone polluted and highly concerned by land abandonment in the Triel-sur-Seine (78) and Carrière-sous-Poissy (78). a. location of the zone, b. a residual land cultivated in cereal crops, c. a residual vegetable cultivation, b. buildings dispersed in the abandoned lands. Source: field visit.

(2). Land abandonment because of soil pollution

The bench of Seine at Triel-sur-Seine (78), Carrière-sous-Poissy (78), and Achères (78) is such a case. As Fig. 5-12a shows, huge patches of agricultural lands severely degraded and most of them are abandoned. Several projects are in progress to give a value to these lands, such as projects of industries, residences, and urban parks. Buildings are dispersed in vast field of abandoned lands, while residual cultivations of cereal crops and even vegetables co-exist (Fig. 5-12b, 5-12c, 5-12d).

(3). Land abandonment because of the instability of wetlands for agricultural use

The two benches of Marne and the valley of La Bassée in the department of Seine-et-Marne are good examples. The first bench of Marne includes Charny, Précy-sur-Marne, Fresne-sur-Marne, Annet-sur-Marne, Jablines, Trilbardou, Vignely, Isles-lès-Villenoy and others. The second bench includes Armentières-en-Brie, Changis-sur-Marne, Congis-sur-Thérouanne, Isles-les-Meldeuses and others. In the valley of La Bassée are concerned especially Montereau-Fault-Yonne, Varennes-sur-Seine, Balloy, Bazoches-lès-Bray, Saint-Sauveur-lès-Bray, Vimpelles, Egligny, Jaulnes, and Villiers-sur-Seine. Lands around lakes and ponds or along rivers are temporarily cultivated as prairies or arable lands but abandoned at another time. Basically, they have similar look with natural habitats except for lands destroyed by sand extraction. Fig. 5-13 shows two photos of abandoned lands in the valley of La Bassée.

Fig. 5- 13. Two abandoned lands in the valley of La Bassée (in Seine-et-Marne). Left: an abandoned crop land near a sand mining, Right: an abandoned prairie. Source: field visit.

2.4.4. Cluster 7: municipalities in strong peri-urbanization

Land abandonment in these municipalities is strongly linked to implantation of urban projects. During the period 1982-2012, these areas were in massive construction and installation of urban open spaces. Abandoned farmlands extensively exist in the interspace of buildings and infrastructures, and land reserve for future construction. Newly abandoned, these lands usually have herbaceous vegetation.

(1). New Town Marne-la-Vallée

The New Town Marne-la-Vallée in the department of Seine-et-Marne is the most striking example. Marne-la-Vallée is the biggest project of Ville-Nouvelle in Ile-de-France, set up since 1965 and concerned 26 municipalities. Municipalities highly concerned by land abandonment during 1982-2012 are also those in massive urbanization, as shown in Fig. 5-14.

The project area of Marne-la-Vallée is sandwiched between the Seine to the north and forests to the south; while to the east, it has already reached the Paris agglomeration. According to the official website of Marne-la-Vallée, several urban development programs, ZAC (Zone d’Aménagement concerté) are in the procedure of creation. The rest agricultural lands thus have a highly uncertain future. Probably this zone will stay for a long time in a landscape comprised by constructions and abandoned farmlands, as actually it is (Fig. 5-15).

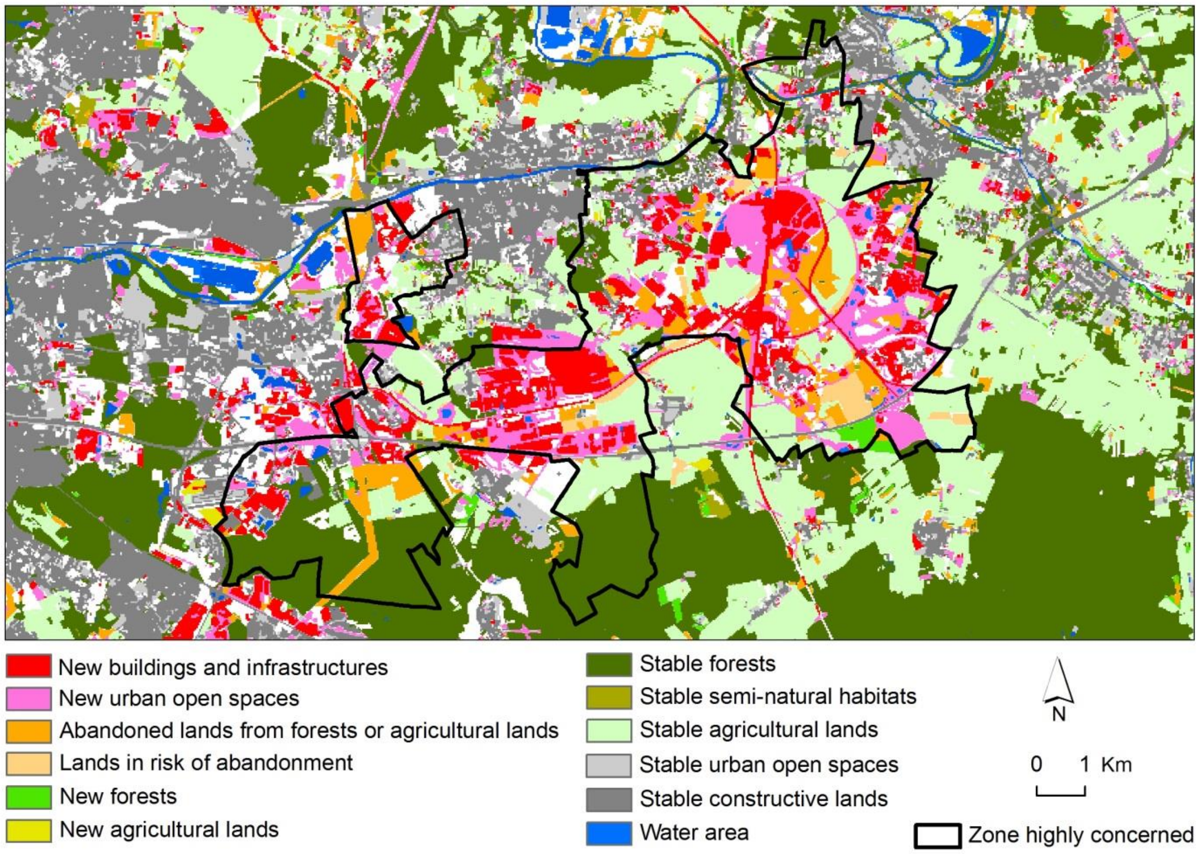


Fig. 5- 14. Municipalities highly concerned by land abandonment of Marne-La-Vallée during 1982-2012. Municipalities concerned: Saint-Thibault-des-Vignes, Croissy-Beaubourg, Collégien, Bussy-Saint-Georges, Chanteloup-en-Brie, Montévrain, Serris, Chessy, Coupvray, Magny-le-Hongre, Bailly-Romainvilliers. All are in the department of Seine-et-Marne.

Fig. 5- 15. Abandoned farmlands near Val-d'Europe in Marne-la-Vallée. Source: field visit.

(2). New Town Saint-Quention-en-Yvelines

The Ville Nouvelle Saint-Quentin-en-Yvelines are not touched strongly by the phenomenon of land abandonment. This zone is surrounded by two agricultural areas, namely, Plateau de Saclay (Essonne) to the south-east and Plaine de Versailles (Yvelines) to the north. Municipalities in the two agricultural areas have strong intentions to protect agricultural lands against urban expansion, in despite of the national project of scientific and technological centre at Saclay. Besides, the Ville-Nouvelle is adjacent with Versailles (78) to the east and the PNR of Chevreuse to the west. Therefore, urbanization here is much more under constraint and the landscape in totally different from Marne-la-Vallée.

(3). Evry-Sénart, Cergy-Pontoise and Pole of the Airport CDG

The other municipalities in Cluster 7 can be mainly distinguished into three sub-zones, the two Ville-Nouvelle of Evry and Sénart, the Ville-Nouvelle Cergy-Pontoise and airport CDG. They are in a similar situation with Marne-la-Vallée but also have some specific characteristics linked to local area. The size of land abandonment is less striking in these three areas than that of Marne-la-Vallée. Municipalities with important land abandonment are not located in the centre of these zones, but in the fringe towards rural area or the Parisian agglomeration.

Fig. 5- 16. Abandoned lands. a. agricultural land to be sold in Goussainville (95), b.abandoned land in Herblay (95), c. Bretigny-sur-Orge (91), d. Coudray-Montceaux (91), e. Combs-la-ville (77), f. Moissy-Cramayel (77). Source: Google maps.

Municipalities around the Airport CDG have abandoned farmlands just outside their urban fringe, such as Gonesse, Goussainville, Louvre and Vémars in the department of Val-d'Oise, as a result of strong willingness for urban development in taking advantage of their particular geographical location. More agricultural lands wait to be sold as constructive lands, such as the one in Goussainville (Fig. 5-16a).

As for the Ville-Nouvelle Cergy-Pontoise, the strongest land abandonment happened in Herblay (95) and Cormeilles-en-Parisis (95), at the side towards the Parisian agglomeration. Caravans are also seen on the abandoned lands (Fig. 5-16b).

In the Ville-Nouvelle Evry-Sénart, abandoned lands appeared in the area cut up by urban expansion and infrastructures on the urban-rural frontier towards Plateau Hurepoix, e.g. in Bretigny-sur-Orge (91) (Fig. 5-16c) and Le Coudray-Montceaux (91) (Fig. 5-16d), and towards the Plateau de la Brie, e.g. in Combs-la-ville (77) cut up by RER and N104 and D57 (Fig. 5-16e) and in Lieusaint (77), Moissy-Cramayel (77), and Savigny-le-Temple (77) by RER, A5 and D306 (Fig. 5-16f).

3. Evolution of the appearance and reuse of abandoned agricultural lands

This section compares the evolution of appearance and reuse of abandoned lands at regional level and among different groups of municipalities (Fig. 5-17). The calculation of area was based upon the principal land use trajectories identified in section 2.2. The figure illustrates the area of reusing abandoned lands as negative value.

The overall trend is that land abandonment has gradually exceeded reuse of abandoned lands. The total study period can be divided into two stages according to the evolution of abandoned lands:

(1). From 1982 to 1999

The area of abandonment and area of reuse both increased in this stage. Different areas had different choices for the reuse of abandoned lands. Municipalities dominated by rural characteristics (Cluster 2 and Cluster 6) had increasing reforestation on abandoned lands from 1982 to 1999. Municipalities under urbanization (Cluster 3 and Cluster 7) used more and more abandoned lands to create urban open spaces.

Especially, in the first three periods (1982-1987, 1987-1990 and 1990-1994), the area of abandonment was almost equal with the area being reused. Then during 1994-1999, abandonment in the rural area (Cluster 2) largely exceeded the area being reused. Most abandoned lands in Auffargis, Cernay-la-Ville, La Celle-les-Bordes and Le-Perray-en-Yvelines in the PNR of Chevreuse were actually abandoned in that period. To the contrary, the areas closely linked to urbanization (Cluster 3 and Cluster 7) had net reduction of abandoned lands. Reuse overpassed abandonment.

(2). From 1999 to 2012

The second stage is from 1999 to 2012. Reuse of abandoned lands became much less important in all four groups of municipalities. However, substantial land abandonment happened in the period 2003-2008. The rise of abandonment in Cluster 6 largely resulted from the ban on cultivation in the polluted area of Triel-sur-Seine and Carrière-sous-Poissy, and the return of cultivated lands to natural wetlands in the valleys. As for other groups, the proportion of meadows rose among the origins of abandoned lands. Especially in Cluster 2, the abandonment of meadows surpassed abandonment of arable lands. The abandonment in Cluster 3 and Cluster 7 was driven by urbanization project, such as the striking example of Marne-la-Vallée. Furthermore, different from the previous stage, little land was left for reforestation and agricultural use increased, especially in Cluster 2.

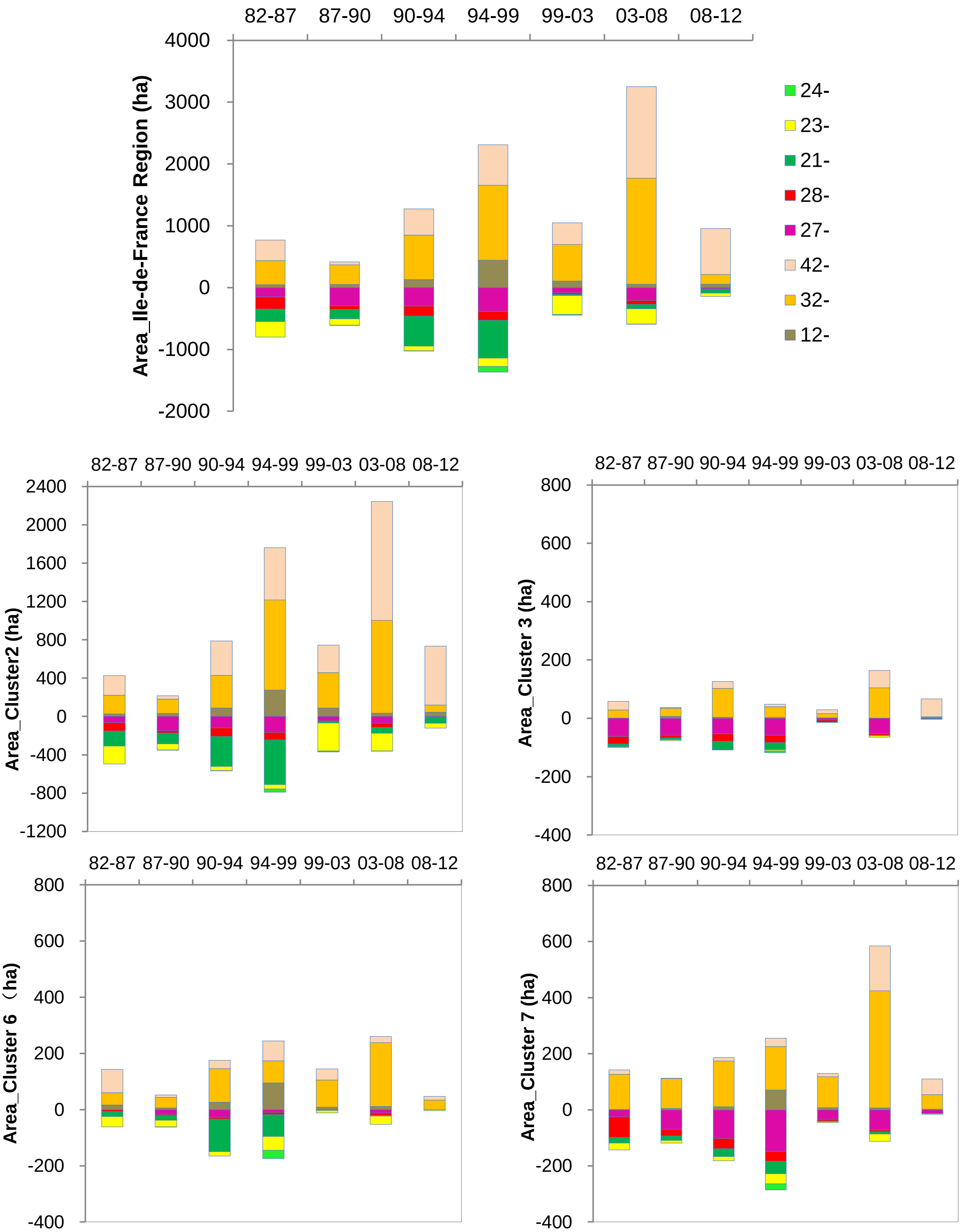


Fig. 5- 17. Evolution of the appearance and reuse of abandoned lands. 24-, using abandoned lands as meadows; 23-, using abandoned lands as arable lands; 21-, using abandoned lands as forest/woods; 28-, using abandoned lands as constructive lands; 27-, use of abandoned lands as urban open spaces. 42-, abandoned lands from meadows; 32-, abandoned lands from arable lands; 12-, abandoned lands from forests/woods.

Thus, the results suggested a continuous decline of agriculture in Ile-de-France. The large surplus of land abandonment in the period 1994-1999 and 2003-2008 in rural area (Cluster 2) suggested that agriculture was in a difficult situation though not under direct threat of urbanization. The area of Cluster 2 is almost three times of the other groups, so the sum at regional level had same trend with that of Cluster 2. The area of agricultural lands abandonment exceeded the return from abandoned lands to agriculture.

On the other hand, less abandoned lands were returned to forests, but more to agriculture. This may be a signal that alternative agricultural forms are needed. As for the area strongly touched by urbanization, there's no doubt that the decline of agriculture was highly linked to urban influences. The period 2003-2008 of massive abandonment was also the moment that the region recovered from a slowing down of new construction because of economic decline from 1994 to 2003 (IAURIF, 2013). According to a study about the consumption of agricultural and natural lands in Ile-de-France (DRIEA, 2011), the increase of built-up area in 2004-2007 was almost twice that in 2000-2004. This situation has possibly given a positive perspective towards future urban development, and thus has encouraged land speculation or land reserve, as the example of Marne-la-Vallée and airport CDG have shown.

4. Social perceptions of ecosystem services and functions of abandoned farmlands

Abandoned lands in peri-urban area have complicated relations with people. When there is no more intervention, the supporting ES (e.g. biodiversity, wildlife habitats ...) and regulating ES (soil fertility, pollination, water regulation…) change, and the lands provide less or no provisioning ES. Abandoned lands thus do not have production-related social economic functions, such as food security, economic return and rural employment. The remaining important functions are related to landscape amenity, such as the opportunities to do walking, hunting, and other recreational activities. It is also possible that a function of waste disposal is illegally imposed on abandoned lands without the waste breakdown ES being provided.

Other actors may come to carry out alternative interventions in order to manage the ecosystem for particular purpose, such as biodiversity, ecological cohesion, open landscape and others. Illegal camping of caravans is commonly seen on abandoned lands in Ile-de-France, which is considered as harm to landscape amenity. People's expectation about the management of abandoned lands, thus depends on their perceptions of the ecosystem services or disservices from those lands and their own social economic situations.

4.1. Differences among actors at different levels

4.1.1. At the individual level

The habitants, farmers, usually perceive abandoned lands according to their personal experiences, so the knowledge of abandoned farmlands varies widely at individual level. The actors in the PNR of Chevreuse commonly reported that there were no or few abandoned farmlands in their municipalities out of various reasons. Some have no idea about abandoned farmlands, for example:

> *« Absolument pas. Je ne vois pas du tout. Je n'ai pas d'idées là-dessus. »* (Absolutely not. I do not see at all. I have no idea about that.) **[H22. Habitant, civil service, Le Perray-en-Yvelines] (5-1)**

Some hardly notice the abandoned lands because they expect a different visual aspect:

« Oui, il y a une friche en face du centre de loisir pas loin de la Mairie. En passant devant je ne les retiens pas forcément. Visuellement ce ne sont pas des espaces délaissés du tout, ils ont un autre aspect. » (Yes, there is a wasteland in front of the leisure center not far from the City Hall. I do not necessarily notice them when I walk by. Visually it is not an abandoned land at all.) **[H52. Habitant, IT engineer, Saint-Rémy-l'Honoré] (5-2)**

Some do not distinguish abandoned lands with fallow lands. Fallow lands are intentionally set-aside by farmers, a practice encouraged by the Common Agricultural Policies (CAP) of European Union (see Chapter 2). For example:

« Les friches je ne suis pas persuadé qu'il y en ait énormément mais il y en a. Par contre, les jachères ici c'est fréquent. De toute façon ici il y a de la forêt. » (I don't think that there are a lot of abandoned farmlands, but there is. To the contrary, there are a lot of fallow lands.) **[H11. Habitant, Secretary in a garage, Cernay-la-Ville] (5-3)**

Many actors think that agricultural lands are abandoned when there is no more property owner, for example:

«Je ne sais pas trop bien ce que c'est. Ce n'est pas lié à la propriété?» (I don't know very much about the abandoned farmlands. Isn't that linked to the property rights?) **[H33. Habitant, cadre, Auffargis] (5-4)**

Whereas, in another area, Triel-sur-Seine, Carrière-sous-Poissy and Vernouillet, massive abandoned exist because of the pollution incident of Achères or pressures of urbanization. Actors are commonly aware of that. For example:

« Le Cœur-Vert c'est pour réhabiliter un peu les espaces en friches. Ils vont faire différentes cultures, notamment du miscanthus et essayer de dépolluer car il y a <u>un peu</u> de pollution. Ils en ont trouvée un peu à cause des eaux d'épandage, surtout depuis 60 mais depuis avec les nouveaux produits (les lessives ...) et puis la pollution due aux voitures, tout doucement par le biais des eaux pluviales c'est arrivé dans la plaine et puis doucement les sols se sont pollués. Le miscanthus, théoriquement doit aider à dépolluer.» (The program of Cœur Vert is for rehabilitation of these abandoned farmlands. The program will promote different cultivations, especially the miscanthus which theoretically will help to decontaminate the soil. The soil has been polluted because of wastewater spreading, detergent, pollution linked to cars that entered soil with the rain.) **[H91. Habitant, Retired, Carrière-sous-Poissy] (5-5)**

« Plutôt oui, j'en ai même autour de chez moi. Sur la route que je prends chaque matin, il y a plus de terre en friche que d'espaces cultivés. » (Yes, there are even abandoned lands around my home. Along the road I take every morning, there are more wastelands than cultivated lands) **[H71. Habitant, real estate agent, Vernouillet] (5-6)**

4.1.2. At the municipal level

In fact in the peri-urban areas, a farmer does not necessarily leave his village when he has totally or partly abandoned agricultural activities. He can still easily declare his property rights over the land. Some farmers just carry out basic practices to avoid the succession towards forests. Residual agricultural lands enclosed by urban areas are still declared in the RPG as set-aside fallow lands.

Bühler and Raymond (2012) also reported that a farmer kept an unfavorable land as "Fallow land" every year. These fallow lands are in fact abandoned lands.

Existence of these lands changes the ecosystem services and functions at the landscape level. The appearance after several years of no management may quickly draw illegal camping of caravans and waste dumping. The municipal managers, i.e. the mayor, service of urbanism and responsible of associations, have rather an overall image about the location of abandoned farmlands and influences in their municipalities. For example:

> « *Après la guerre il y a eu une déprise de terres agricoles importante, le nombre de fermes a diminué entre 1960-70, de 20 fermes à 7… et donc en 1993 on avait 145 h de terres cultivés, et les friches représentaient 110h… donc vous voyez l'évolution… et le but de l'Association pour le Développement de l'Agriculture Périurbaine A Vernouillet et ses Environs (ADAPAVE) c'était donc de remettre en culture ces friches* » (There was important land abandonment after the War. The number of farms decreased during 1960s-70s from 20 to 7. In 1993, we had 145 ha cultivated lands, and 110 ha abandoned farmlands. The objective of the association ADAPAVE was to return the lands into agricultural lands.) **[As7. President of the Association ADAPAVE, Vernouillet] (5-7)**

> *«Il y a les fonds de vallée, c'était cultivé jadis et maintenant ça repousse, c'est à l'abandon, c'est de la friche. Ça s'appelle la Brelinquinerie, cela appartient à Monsieur XX, il ne veut rien faire du tout. Il laisse comme ça, il s'en sert peut-être pour la chasse, mais c'est la fermeture des fonds de vallée, c'est inquiétant. Cela ferme les paysages, il n'y a plus d'entretien, la terre n'est plus économiquement rentable.»* (In the valley, there are abandoned lands, which used to be cultivated. The lands belong to Mr. XX. He does not want to do anything and just leaves the lands in that way. Maybe he keeps the lands for hunting, but that closes the valley and the landscape. There is no intervention, and the lands are not economically profitable anymore.) **[E4. Mayor of La-Celle-les-Bordes] (5-8)**

> *«300 caravanes pour une petite ville comme la nôtre c'est vraiment trop pour les gérer correctement… C'est pour cette raison que nous avons demandé aux agriculteurs possédant des friches et des jachères de faire une limite infranchissable entre la voirie et ces espaces, en créant des fossés. Pour une commune de 1600 habitants il est difficile d'intervenir, car ils s'installent pour 15 jours, 3 semaines. Nous ne voulons pas forcement réinvestir ces espaces en friche car pour nous… ils peuvent rester comme ça… pour toutes les raisons qu'on vient d'énumérer [les services écosystémiques que nous avons énumérés dans les tableaux] … Les friches en elles-mêmes ne gênent pas car elles apportent une diversité dans le paysage mais on a dû intervenir »* (Having 300 caravans for a small town like ours is really too much for a correct management... This is why we asked the farmers who have abandoned lands or fallow lands to keep an inaccessible boundary between the roads, a ditch for example. Our town has 1600 inhabitants, and it is difficult to intervene in the management of caravans because they settle for 15 days, three weeks. We don't necessarily want to reinvest those abandoned lands because for us ... they can stay like that ... for all the reasons we just listed... The abandoned lands do not bother us because they provide diversity in the landscape, but we had to intervene.) **[E1. Mayor of Cernay-la-ville] (5-9)**

4.1.3. Coordination of the PNR of Chevreuse

The PNR of Chevreuse is dedicated to enhancement of the territory cohesion. The managers of PNR are even in a higher level than the municipal representatives. They have the duty to coordinate the interests of different actors including farmers, habitants, and other stakeholders like the regional planner and environmental associations in Ile-de-France. Therefore, the managers of PNR have a wide range of interests, including economic and social development, climate change, environment quality, landscape amenity, biodiversity, and others, as claimed in the Charter of PNR (see Chapter 4, section 1.2). The following are some evidences obtained in the interviews for such roles of PNR:

> *« L'adhésion à la charte du PNR se fait sur la base du volontariat. Pour l'instant 30 agriculteurs ont souhaité participer aux programmes agricoles proposés par la charte. »* (Joining the PNR charter is done on a voluntary basis. For now 30 farmers have participated in the agricultural programs proposed by the Charter.) **[Responsible for agriculture in the mix syndicate of the PNR de Chevreuse] (5-10)**

> *« Le Parc nous aide beaucoup, comme en face du cimetière, la restructuration de terres qui étaient moitié en friche moitié en prairies humides, nous avons passé une Convention avec le Parc, qui va gérer toute cette prairie pendant 20 ans. »* (The Park helps us a lot, like rearranging a land in front of the cemetery. The land was half abandoned half as wet meadow. We had a convention with the Park, and they will help to manage the whole meadow for 20 years.) **[E4. Mayor of La-Celle-les-Bordes] (5-11)**

> *« Donc nous avec le Parc on a quelques parcelles où on a le droit de faire pâturer nos animaux mais par exemple il faut que le papillon ait fini de nidifier, il faut que telle orchidée soit fanée avant de pouvoir mettre les animaux en pâturage. Pour le PNR c'est intéressant pour la gestion des friches. C'est le PNR qui fixe les dates par Convention, avec [XX, nom de personne] du PNR qui s'occupe de la biodiversité du Parc.»* (So we, in the Park, have the right to graze our animals on several fields, but for example it is necessary to wait until the butterfly has finished nesting, or a certain kind of orchid is faded. For PNR, this is an interesting solution for the management of abandoned farmlands. It is the PNR who sets the dates. We have a convention with the responsible of PNR who is in charge of the biodiversity.) **[A4. Organic farmer, La-Celle-lès-Bordes] (5-12)**

4.2. Comparison of social perceptions between two study areas

The two study areas, namely, the PNR of Chevreuse and the bench of Seine including Triel-sur-Seine, Carrière-sous-Poissy and Vernouillet (TCV), have different geographical, social and economic conditions (see Chapter 4, section 1.2). The social perceptions of abandoned farmlands have both convergences and divergences.

Table 5-8 presents the number of positive responses ("Yes") v.s. negative responses ("No") in the two areas and in total for specific ecosystem services (ES) or disservices (DS) and for reuse choice of abandoned farmlands, based upon the binary data in Table 4-3 (section 5-2 of Chapter 4). Because the interviewees were invited to choose no more than 5 items for each questionnaire (e.g. feelings towards abandoned lands), the answer "No" for one ES/DS does not necessarily mean that the interview denied it, but that the ES/DS is less important than others.

Table 5-8 also presents the results of binomial tests (test p = 0.5) on the predominant response ("Yes" or "No") for each ES/DS and reuse choice. Imaging there is a vote to decide if the PNR should convert abandoned farmlands into urban area, and if all the people in PNR vote, we can be statistically sure that the result of the vote will be "no", according to Table 5-8. Similarly, the tests on the responses for ES/DS reveal the predominant attitudes of the people in different areas, which will influences on their choices regarding management of abandoned farmlands.

The results suggest a significant convergence between PNR and TCV for ES2 (wildlife habitats) and DS2 (obstruction of landscape) and Uurb (using abandoned lands for urbanization) and a divergence for ES6 (entertainment), ES7 (education), ES8 (esthetic service) and Ueco (ecological use of abandoned lands). Referring to the conversations with actors, the convergences and divergences between two areas are as follows:

Table 5- 8 Binomial tests on actors' perception towards the ES/DS and reuse of abandoned lands in different areas

	All			**PNR of Chevreuse**			**Triel, Carrière and Vernouillet**		
	n (Yes)	**n (No)**	**Sig.**	**n (Yes)**	**n (No)**	**Sig.**	**n (Yes)**	**n (No)**	**Sig.**
ES1	22	27		12	15		10	12	
ES2	48	1	Yes (***)	26	1	Yes (***)	22	0	Yes (***)
ES3	32	17	Yes (**)	18	9		14	8	
ES4	22	27		14	13		8	14	
ES5	23	26		14	13		9	13	
ES6	16	33	No (**)	7	20	No (**)	9	13	
ES7	29	20		12	15		17	5	Yes (**)
ES8	14	35	No (***)	5	22	No (***)	9	13	
DS1	29	20		15	12		14	8	
DS2	12	37	No (***)	6	21	No (***)	6	16	No (*)
Uagr	31	18		17	10		14	8	
Uurb	8	41	No (***)	4	23	No (***)	4	18	No (***)
Ueco	19	30		7	20	No (**)	12	10	
Urec	24	25		12	15		12	10	

Notes: [1]Predominant response (test p=0.5) and its significance level were indicated for each test: * Sig. = 0.1; **Sig. = 0.05; ***Sig.5 = 0.01. [2]The significance level of the test on ALL and PNR of Chevreuse were calculated based on Z approximation. [3] ES1: biodiversity; ES2: wildlife habitats; ES3: pollination; ES4: water or climate regulating; ES5: resistance to natural risk; ES6: entertainment; ES7: education; ES8: esthetic service; DS1: illegal waste dumping or camping; DS2: obstruction of landscape. Uarg: used as agricultural lands; Uurb: used for urbanization; Ueco: protected for ecological interest; Urec: used for recreation.

4.2.1. Convergences between the two areas

It is commonly recognized in both PNR and TCV that the abandoned farmlands are natural ("naturel") and wild ("sauvage") spaces, which can provide habitats for the wildlife. Such spaces may lead to positive feelings, but also bad ones because of the risk being attacked by big animals, or the illegal waste dumping and camping. For example:

> « *[Les espaces de prairie] sont une sécurité pour l'inondation, dans notre cas et cela nous permet de clore le reste des prairies pour laisser passer le grand gibier, ça fait une petite soupape. C'était leur passage naturel donc on ne va pas les contrarier, on essaye de prendre en compte tout l'ensemble et on voit où ils passent donc on va clore plus loin plutôt que de le faire en limite de propriété.* » (The meadows protect us against flooding. Maintaining meadows also allow us to take care to not disturb the natural passage of the wild animals.) **[A4. Organic farmer, la Celle-les-Bordes] (5-13)**

> « *La friche oui bien sûr… elle peut être considérée comme un espace sauvage… naturel… après le définir plaisant ou agréable c'est peut-être trop… si vous voyez ce que je veux dire… ici par exemple, je n'ai pas envie de m'y promener dedans… parce que il n'y a pas des sentiers… après c'est mieux comme ça qu'avec des bâtiments partout… mais m'y promener*

dedans… alors là je ne dirais pas que j'ai peur mais on ne sait pas ce qu'on va trouver » (The abandoned farmlands can be considered as a wilderness, of course. Then, "pleasant" or "enjoyable", perhaps goes too far, if you know what I mean here ... For example, I do not want to walk there in it, because there are no trails ... then, it's better to keep it in that way than with buildings around, but imaging walking in it… I would not say that I'm scared but we do not know what we'll find there.) **[H84. Habitant, Secretary of Mayor, Triel sur Seine] (5-14)**

« La friche ça peut être sympa, s'il n'y a pas de papiers ni d'ordures. Si on y met des dépôts sauvages ça gâche tout. Et il y en a pas mal dans le secteur. » (Abandoned farmlands can be nice when there is no paper or garbage on the land. The illgal waste dumping ruins everything. There are a lot around.) **[H75. Habitant, professor of dancing, Vernouillet] (5-15)**

« La friche… oui, elle représente un espace naturel mais en même temps risqué… qui pose problème… car il n'est pas clôt, pas cultivé et que ça peut vite devenir un dépotoir. Dès qu'on laisse un espace vide, abandonné… les gens l'utilisent pour eux… Il faudrait en interdire l'accès par des barrières ou des fossés » (Abandoned farmlands represent a natural space but also risk. There are problems. Because the lands are not fenced or cultivated, they quickly become area of illegal waste dumping. There should be fences or ditches to block the access into the lands.) **[H13. Habitant, retired, former director of a conservation association, Cernay la Ville] (5-16)**

« *Les deux friches que nous avons sur la commune sont devenues… pratiquement… des aires d'accueil pour les gens du voyage. On a été envahi par des campements de 150 à 300 caravanes. Il existe des réglementations concernant les gens du voyage, notamment sur la création d'aire d'accueil, la communauté de communes en possède, mais elles ne peuvent accueillir que quelques caravanes… une dizaine au maximum […] les habitants bien évidement sont concernés par ces espaces lorsqu'il y a des campements qui s'y installent. Mais les friches font partie du quotidien, on est habitué à les voir, elles ne nous dérangent pas mais les habitants ont compris les problèmes que peuvent créer ces espaces*» (The two abandoned farmlands in out municipality have become the halting sites for Travellers. We're invaded by 150~300 caravans. We have policies to create halting sites for the Travelers but it's only possible to receive several, a dozen at the maximum, caravans. They don't disturb us but the habitants understand the potential problems of these spaces.) **[E1. Mayor of Cernay-la-ville] (5-17)**

The disservice of obstructing landscape is not significantly reported in either PNR or TCV, but has been mentioned by some actors in PNR, for example, the Mayor of La-Celle-les-Bordes and a farmer:

« J'ai fait la visite d'une friche boisée avec l'inspecteur des sites du PNR. Je l'ai emmené sur des endroits qui sont des cônes de vue, qui doivent être protégés pour la vision des paysages, mais ils se ferment naturellement, les arbres poussent, on ne va pas empêcher les arbres de pousser... On ne peut pas demander au propriétaire de couper son sapin de 5 mètres de haut. (...) Vous pouvez faire attention quand il arrive quelque chose... Mais la raison c'est que le propriétaire est chez lui et il ne veut pas être embêté. Il a au moins 70 ha, il est chez lui il fait ce qu'il veut, dans la mesure où il n'y a pas d'infraction.». (I made a visit to a wooded wasteland with the field investigator of PNR. I took him to some viewpoints, which must be protected for the vision of the landscape, but they are closed naturally. Trees are growing. We cannot ask the owner to cut the tree over 5 meters. ... You should pay attention for something happens ... But the land owner is at home and he does not want to be bothered. He has at least 70 ha. He stays at

home and does what he wants, to the extent that it is not an infringement.) **[E4. Mayor of La-Celle-les-Bordes] (5-18)**

Urbanization on abandoned farmlands is not welcome in either PNR or TCV, as shown in the quotation 5-14 and others:

> *« L'objectif de la remise en culture est de donner une utilisation au sol car un sol sans utilisation agricole est potentiellement, un jour, un site qui peut être urbanisé. L'urbanisation va là où elle peut aller, où les espaces ne sont pas utilisés, donc un espace de friche, un espace vide tente les promoteurs. Donc on y répond par le cœur vert, pour nous clairement la friche urbaine est un espace à réhabiliter et la friche agricole doit garder sa vocation agricole. »* (The objective of re-cultivation is to give the abandoned land a utility, because when left vacant it will be urbanized one day. The abandoned lands attract developers. Therefore, we created this program of Coeur Vert. We think that urban wasteland should be developed but abandoned farmlands should preserve its agricultural vocation.) **[E9. Director of the service of urbanism, Carrières-sous Poissy] (5-19)**

> *« Alors… moi personnellement je ne suis pas pro mais après politiquement je ne m'en suis pas occupé, donc je n'ai pas forcement une opinion là-dessus mais bon… plus on ajoute des logements, plus derrière on doit gérer des voitures, des stationnements… c'est clair…* (Personally, I'm not for the project of construction; then politically I'm not interested, so I don't have an opinion on that issue. However, increase of residences means also to manage the traffic, parking and others, so it's clear…) **[H53. Habitant, Director of a recreational center, Saint-Rémy L'Honoré] (5-20)**

> *« Ok… Alors… déjà la remise en culture dans notre commune on a vu comme elle est impossible donc je dirais non… après si on pense aux autres espaces… dans la commune… pas pour l'urbanisation… du moins pas pour l'instant…loisirs éventuellement… pour la faune oui… les animaux ont été mis en difficulté par l'urbanisation mais après les gens, les agriculteurs disent qu'il y a trop de sangliers et alors… chacun a ses propres intérêts…»* (Re-cultivation on these abandoned farmlands is impossible in our municipality. Not for urbanization, yes for recreational space if it is needed, yes for the fauna. Urbanization has made the living difficult for wild animals, but the farmers said there are too many wild boars. Everyone has different interests.) **[H85. Habitant, historian, Triel-sur-Seine] (5-21)**

4.2.2. Divergences between the two areas

Abandoned lands have different statues in the PNR and TCV. They are considered highly ecologically interesting at the level of PNR and are important elements in environmental documents. Whereas in TCV, abandoned lands have rather a negative image because of pollution. The elected representatives have a strong willing and pressure to reuse the lands, and have created several big projects (see section 1.2 of Chapter 4). However, habitants in TCV appreciate abandoned lands more as natural spaces or recreational spaces; because the PNR has a strongly protected natural environment while the area TCV has an urban environment.

According to Table 5-8, TCV recognized more the ES of education (e.g. discovering of fauna and flora), entertainment and esthetic services of abandoned lands. Some quotations:

Je suis pour la sauvegarde de ces deux espaces en friche. Surtout étant jeune maman, on en a besoin pour les enfants à condition de les entretenir un minimum… si on les aménage en espace de loisir je pense que beaucoup de familles pourront en profiter » (I support to protect the abandoned farmlands. As a young mother, I need these spaces for my child. We just need some minimum interventions. If we maintain the abandoned lands as recreational spaces, it will benefit a lot of families.) **[H82. Habitant, agent in a nursing home, Triel sur Seine] (5-22)**

« Je préfèrerai que les arbres reviennent, que l'on fasse quelque chose dessus. C'est bien une forêt, ou sinon faire des récoltes. Soit on laisse en l'état pour faire une forêt et on peut y aller en famille ou on fait des cultures mais avec un objectif. Pour l'instant il est inutile mais qu'il y ait quelque chose d'utile à y faire. (I would prefer to leave the abandoned lands in the state to become a forest and you can visit it with family, or return them to agriculture with a purpose. For now they are useless but there is something useful to do with them.)

Oui c'est important, c'est notre nature, on est en région parisienne il nous faut un peu de nature. (Yes, it's important. We are in the Parisian Region, so we need a little natural space.)

Nous on se promène là-dedans, donc pas d'urbanisation. On a la chance dans le 78 d'avoir beaucoup de verdure, il faut que ça reste ». (We walk in the abandoned farmlands, so there is no urbanization. We are lucky in the department of Yvelines to have a lot of greenery. It should remain in that way.) **[H86. Habitant, employee of a driving school, Triel-sur-Seine] (5-23)**

« C'est un peu regrettable mais connaissant un peu le passé de certains terrains, il n'y a pas beaucoup de marge de manœuvre. Je verrai une utilisation autre que de la construction ou de la culture sur ces terrains. Oui mais pas de constructions supplémentaires. Plutôt des espaces récréatifs, balades, coins pour manger, petits sentiers… » (Knowing a bit the past of certain lands, there is not much leeway. I'll support another use other than construction or cultivation on the lands. No additional constructions. It would be better to use as recreational areas, for ballads, eating, small paths and others.) **[H82. Habitant, agent in a nursing house, Triel-sur-Seine] (5-24)**

However, it does not mean that people in PNR don't value the service of education, for example:

«On souhaiterait avoir des espaces un peu plus naturels sur Saint-Rémy L'Honoré en lien avec les activités pédagogiques que proposent les centres socio-culturels ou les écoles par exemple. Même si je reconnais qu'il faut loger les gens. Je pense qu'il fait vraiment réfléchir sur ces espaces pour pouvoir leur donner une utilité adéquate » (We would like to have a little more natural spaces in Saint-Rémy-l'Honoré linked to educational activities proposed by the socio-cultural centers or schools for example. Although I agree that we should accommodate people, I think we should really think about giving adequate utility to these lands. **[H52. Habitant, IT engineer, Saint-Rémy L'Honoré] (5-25)**

In TCV, there are different perceptions about the big projects for returning a utility to the polluted lands, for example revealed for example by comparing the quotation 5-19 and the following one of a habitant:

« Oui nous sommes un peu au courant mais moi-même je n'ai pas tout compris. Je trouve que leurs explications (celles de la mairie) ne sont pas claires. Ce sont des terrains mis à plat, défrichés, où ils plantent du miscanthus, qui meurent d'ailleurs. Je ne suis pas très pour le projet « Cœur Vert », on nous mobilise nos terrains qu'on nous rachète une bouchée de pain. Je

ne suis pas touchée, mais mes sœurs oui. Il n'y a pas eu de concertation entre la ville et les propriétaires de ces terrains. Il n'y a même pas eu de courrier, l'annonce a été faite verbalement. » (Yes, we know a little about that, but I do not understand well. I find that their explanations (of the municipality) are not clear. They flatted the land, cleared it up, and planted the miscanthus, which has died. I 'm not for the program of "Green Heart ". It mobilizes our lands with a very low price. I am not affected, but yes my sisters. There was no consultation between the city and the owners of these lands. There was even no mail, the announcement was made orally) **[H86. Habitant, employee of a driving school, Triel sur Seine] (5-26)**

The PNR does not show a significant interest in the entertainment and esthetic service of abandoned lands. The farmers are bothered the disservices from abandoned lands, or think that agricultural lands can also provide the ecological interests:

« Ca n'a rien avoir avec un bois, c'est des ronces on ne peut pas y entrer c'est au milieu du champ. C'est une obstruction du paysage à la limite […] nous on la combat la friche tout le temps. Sur nos terrains on désherbe le long des grillages, on coupe des jeunes arbres […] Nous par exemple nous avons deux parcelles divisées par une friche qui est devenue désormais un bois… Histoire du boulanger parisien retraité qui avait acheté cette parcelle. Il avait envisagé de clôturer et d'en faire un jardin. Ce monsieur de 90 ans est décédé et personne n'a repris. Et le défrichement maintenant c'est trop couteux… » (It has nothing to do with woods. They are thorn bushes, and make it difficult to enter in the fields. This is an obstruction of the landscape at the edge... We are always fighting with the wastelands. We cut down the young trees along the fence...We for example have two plots divided by a wasteland which has become a wood ... A retired baker from Paris had bought the plot. He intended to make it into a garden. He died at 90 years old, and nobody takes the plot. Now it is too expensive to clear up the land....) **[A6. Farmer, Saint-Rémy-Lès-Chevreuse] (5-27)**

« *Oui. Elles n'ont pas d'utilité (les friches). Les réinvestir ça peut être une occasion pour valoriser les terres, les travailler… comme c'étaient des mauvaises terres, pas faciles d'accès, trop humides… Après oui… il y a des intérêts écologiques… mais on peut en avoir aussi en retravaillant les terres »* (The abandoned farmlands don't have utility. Reinvestment can be an opportunity to value the land. These are not good lands, not easy to access or too wet ... They have ecological interests ... but recultivation on abandoned lands can also have ecological interests.) **[A1. Farmer, Cernay la Ville] (5-28)**

The habitants not necessarily prefer recreational spaces, for example:

Ah oui, clairement… autre chose plutôt que des logements… un parc par exemple… un espace vert pas forcement de loisir mais vert quoi… » (There can be something else rather than housing, a park for example, a green space not necessarily recreational.) **[H53. Habitant, Director of a recreational center, Saint-Rémy L'Honoré] (5-29)**

Most of the actors do not favor the ecological use of abandoned farmlands according to Table 5-8. Ecological use means to leave the abandoned lands progressing into forests. Ecological use can also be a minimum management of abandoned lands to cut down the succession towards forests, but always for ecological interests, for example:

Nous devons absolument limiter l'avancée de la forêt… parce que nous en avons déjà en grande quantité… en ce sens les friches… si on ne les gère pas… si on les entretient pas… peuvent évoluer naturellement vers un stade forestier… et donc, nous en tant que PNR, nous sommes pour une gestion écologique de ces espaces… » (We should definitely control the advancement of forests, because we have already a lot. The abandoned farmlands evolve naturally towards forests if there is no intervention. Therefore, we, as a PNR, support the ecological management of these lands.) **[Responsible for agriculture in the mix syndicate of the PNR de Chevreuse] (5-30)**

The result that most of the actors in PNR do not favor ecological use does not mean they are not interested in ecological value. They just do not favor the strategy with a pure objective of ecological use, for that they do not want the lands to develop into forests (quotations 5-8) or the problems of illegal waste dumping and camping (quotations 5-15, 5-16 and 5-17) when the lands are left "vacant". Instead, they would rather support for example agricultural activities combing ecological concerns (see quotation of 5-12, 5-27, 5-28) and the following:

« On a sorti de cet espace 120 stères de bois et on a enlevé 35 bennes de 10 m^3 de déchets de toute nature, sans compter les carcasses de voiture. On a donc réhabilité ce milieu, on l'a clôturé et fauché et on l'a laissé tranquille pendant un ou deux ans et maintenant c'est un superbe pré de 6 ha qui abrite de mai à décembre 6 vaches Blondes d'Aquitaine et leurs petits veaux.».(We removed from this space 120 m^3 of timber, 35 waste bins, 10 m^3 each, containing all kinds of wastes, and also abandoned car wreck. We then rehabilitated this space, fenced and cleared it, and allowed the vegetation to recover for a couple of years. Now it is a superb meadow of 6 ha, grazed by 6 cows and their calves from May to December. **[E6. Deputy Mayor in charge of environment of Saint Rémy-lès-Chevreuse] (5-31)**

4.3. Three categories of actors identified with hierarchical clustering analysis

As the previous section has shown, same attitudes are shared by actors in the PNR and the TCV. Except for the divergences discussed above, the population does not show a significant tendency regarding the perceptions of ES/DS and reuse choices according to the geographical location. The responses are rather composed by a half "yes" and half "no".

Therefore, as a complement, I did a hierarchical clustering analysis to classify the actors based upon the set of responses of each actor for ES/DS and the reuse choice of abandoned farmlands. The classification results in three categories of actors (Fig. 5-18). The label in the Fig. 5-18 indicates the codes of actors, for example, H75 means the fifth habitants interviewed in Vernouillet, and A3 is the farmer in Auffargis, because the study contacted only farmer in each municipality. The result suggests that farmers, habitants and elected representatives dispersed in all the three categories. As for the geographical area, Category 1 includes five actors from the PNR, and seven from the TCV; Category 2 includes thirteen actors from the PNR and five from the TCV; Category 3 includes six actors from the PNR and eight from the TCV. Thus, the geographical area or social category does not determine a specific bundle of perceptions for ES/DS.

It is unrealistic to classify the actors asking for same responses for every ES/DS. However, it can be done by the identification of dominant determinants for each category. Similarly to section 4.2 for the two geographical area, I carried out binomial tests (test p = 0.5) on the predominant response ("Yes" or "No") for each ES/DS and reuse choice in each category. Table 5-9 presents the results of the binomial tests. Observation on the ES/DS or reuse choices that have passed the significant level helps to reveal the dominant factors (e.g. perception of a certain ES/DS) in each category and thus to define the three groups identified. It also reveals the relations between actor's perceptions of different ES/EDS and his reuse choice. For example, is there positive relation between high recognition of esthetic service and high recognition of recreational service? Does the recognition of certain ES/DS influence on the choice of reusing abandoned lands?

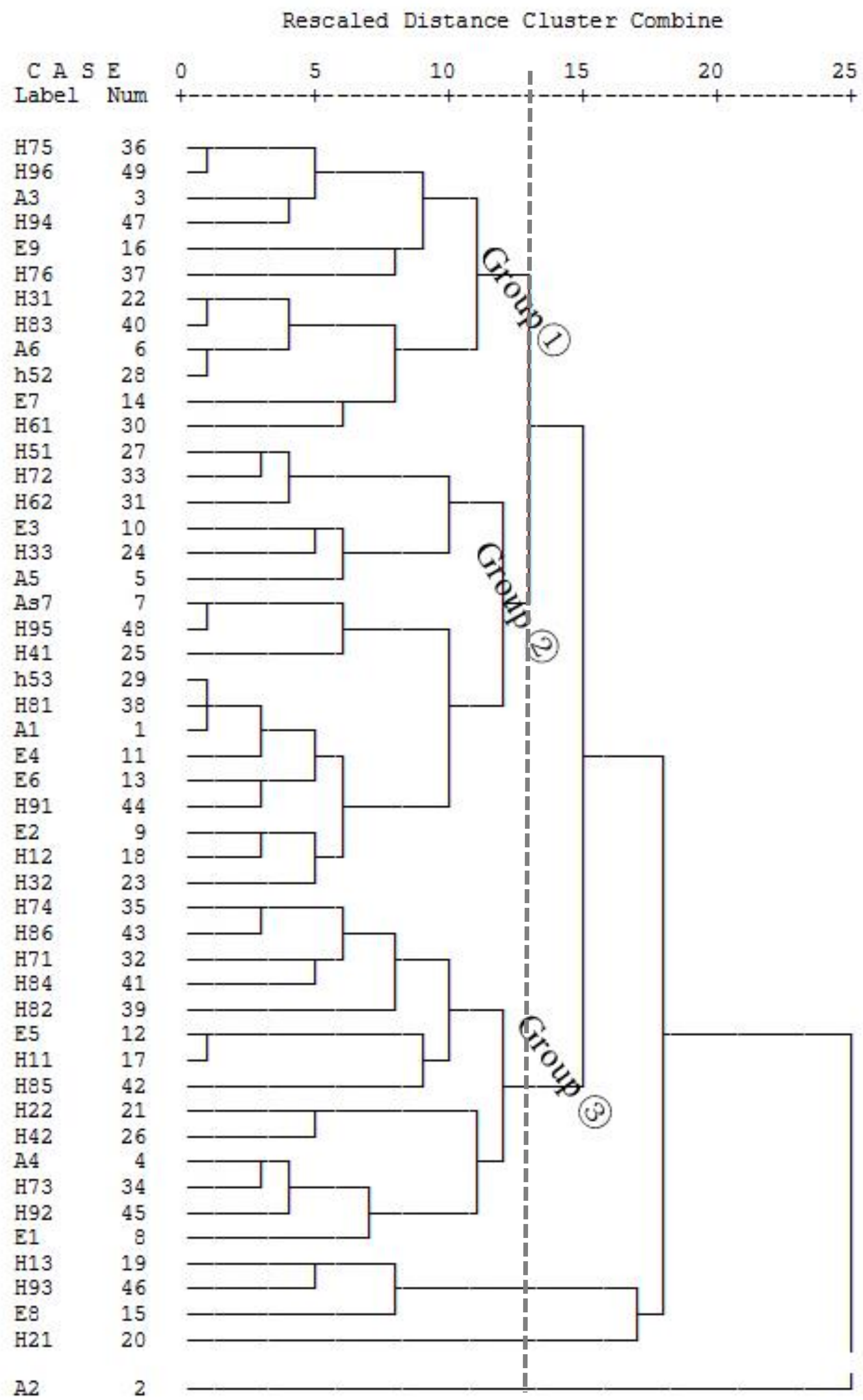


Fig. 5- 18. Dendrogram of actors in terms of perceptions of ES/DS from abandoned lands.

The label of actors in Fig. 5-18 is marked by a letter (H: habitants; A: farmers; E: municipal authorities; As: environmental associations), followed by the code of municipalities (1. Cernay-la-Ville, 2. Le Perray, 3. Auffargis, 4. La Celle-les-Bordes, 5. Saint-Rémy-l'Honoré, 6. Saint-Rémy-lès-Chevreuse, 7. Vernouillet, 8. Triel-sur-Seine, 9. Carrière-sous-Poissy) and then the order of actors in the same municipality if more than one actors were interviewed. For example, H75 means the fifth habitants interviewed in Vernouillet.

Table 5- 9 Binomial tests on actors' perception towards the ES/DS and reuse of abandoned lands in different categories

	Group 1			**Group 2**			**Group 3**		
Number of actors from two areas[4]	5 (PNR)	7 (TCV)		13 (PNR)	5 (TCV)		6 (PNR)	8 (TCV)	
	n (Yes)	**n (No)**	**Sig.**	**n (Yes)**	**n (No)**	**Sig.**	**n (Yes)**	**n (No)**	**Sig.**
ES1	1	11	No (***)	14	4	Yes (**)	7	7	
ES2	12	0	Yes (***)	18	0	Yes (***)	14	0	Yes (***)
ES3	10	2	Yes (**)	15	3	Yes (***)	7	7	
ES4	0	12	No (***)	15	3	Yes (***)	5	9	
ES5	7	5		7	11		9	5	
ES6	2	10	No (**)	0	18	No (***)	14	0	Yes (***)
ES7	7	5		11	7		10	4	
ES8	2	10	No (**)	4	14	No (**)	8	6	
DS1	12	0	Yes (***)	12	6		3	11	No (*)
DS2	4	8		4	14	No (**)	1	13	No (***)
Uagr	10	2	Yes (**)	11	7		6	8	
Uurb	3	9		1	17	No (***)	1	13	No (***)
Ueco	6	6		5	13	No (*)	7	7	
Urec	7	5		5	13	No (*)	10	4	

Notes: [1]Predominant response (test p=0.5) and its significance level were indicated for each test: * Sig. = 0.1; **Sig. = 0.05; ***Sig.5 = 0.01. [2]The significance level of the test on ALL and PNR of Chevreuse were calculated based on Z approximation. [3]ES1: biodiversity; ES2: wildlife habitats; ES3: pollination; ES4: water or climate regulating; ES5: resistance to natural risk; ES6: entertainment; ES7: education; ES8: aesthetic service; DS1: illegal waste dumping or camping; DS2: obstruction of landscape. Uarg: used as agricultural lands; Uurb: used for urbanization; Ueco: protected for ecological interest; Urec: used for recreation. [4]The numbers of actors from PNR and from the bench of Triel, Carrière and Vernouillet in each group.

According to Table 5-9, all the actors have the response "yes" for ES2 (wildlife habitats), as already explained in section 4.2.1. The three groups all have half "yes"–half "no" response for ES5 (resistance to natural risk) and ES7 (education). The rest items indicate the differences among the groups:

First, the perception on ES6 (entertainment/recreation) and DS1 (illegal waste dumping and camping) distinguish Group 3 from the rest two groups, but DS (1) is less significant than ES6. Group 3 also differs from the other two groups for ES3 (pollination) and ES8 (aesthetic service). Group 3 have a half-half pattern for both ES3 and ES8, while the other two groups have significant recognition of ES3 (10/12 "yes" in Group 1 and 15/18 "yes" in Group 2), and little recognition of ES8 (10/12 "no" in Group 1, 14/18 "no" in Group 2).

Then, Group 1 and Group 2 have significant opposite tendencies for ES1 (biodiversity) and ES4 (water or climate regulating). Group 1 has little recognition of neither ES1 (11/12 "no") nor ES4

(12/12 “no”). Group 2 has significant recognition of both ES1 (14/18 “yes”) and ES4 (15/18 “yes”). Group 1 also has significant recognition of DS1 (illegal waste dumping and camping, 12/12 “yeas”), but Group 2 has a half-half pattern (12/18 “yes). Group 2 has little recognition of DS2 (obstruction of landscape, 14/18 “no”), and the Group 1 has a half-half pattern (8/12 “no”).

Therefore, Group 3 has a high appreciation for entertainment/recreational service, and little influenced by the problem of illegal wastes dumping and camping. Group 2 is marked by a high appreciation of environmental values of abandoned lands, i.e. biodiversity, pollination, water and climate regulating. The actors of Group 2 are not much bothered by the problem of landscape obstruction, and the aesthetic service is not quite important. Group 1 is marked by a high appreciation of pollination and awareness of the problem of illegal waste dumping and camping. They don’t care much about the environmental services like biodiversity, water and climate regulating, or the recreational aesthetic service.

Looking into the choice of reuse, Group 1 shows significant willingness for agricultural use (10/12 “yes”). Thus, the determinants for the three groups are the “Agricultural potentials” (Group 1), “Environmental values” (Group 2), and “Recreational values” (Group 3) of abandoned lands, respectively.

This characterization is in accordance with the conversations quoted in the previous sections. Examples for Group 1 (“Agricultural potentials”): the Director of urbanism of Carrières-sous Poissy (E9, quotation 5-19) think that abandoned farmlands should preserve its agricultural vocation; the farmer in Saint-Rémy-Lès-Chevreuse (A6, 5-27) cut down the young trees along the fence to fight with the abandoned lands near his fields.

Group 2 rejects the ideas to use abandoned lands for urbanization (17/18 “no”), ecological use (13/18 “no”) and recreational use (13/18 “no”). It suggests that they would prefer agricultural use for environmental concerns. A half of the actors from the PNR are in this group (13/27). Many quotations confirm this tendency, for example: the organic farmer in La-Celle-lès-Bordes (A4, 5-12), and the farmer in Cernay la Ville (A1, 5-28) have conventions with the PNR to adopt environmental friendly practices. The deputy Mayor in charge of environment of Saint Rémy-lès-Chevreuse (E6, 5-31) talked about their project to open an abandoned land to let the farmer grazing cows from May to December. For group 2, a green space on abandoned lands does not necessarily need to be recreational, as the Director of a recreational center in Saint-Rémy L’Honoré said (H53, 5-29).

For Group 3, the actors appreciate the “recreational values”, for example the agent in a nursing house in Triel-sur-Seine (H82, 5-24) support another use other than construction or cultivation on the abandoned lands, like recreational areas for ballads, eating, small paths and others. The employee of a driving school in Triel-sur-Seine visits the abandoned lands regularly for walking with her family (H86, 5-23).

Conclusions

This part has conducted a multi-level approach to study the problems linked to the management of abandoned farmlands in the Ile-de-France Region. It combines a regional pattern analysis on the location and conversions of abandoned farmlands with investigations at two local areas about the perceptions of different stakeholders.

The regional analysis has identified ten categories of land use change based upon trajectories through 1982-2012. It suggests that abandoned farmlands are important elements in the peri-urban areas of Ile-de-France.

There are four groups of municipalities and each has a different situation of land abandonment, including two groups in rural area and two groups in urban area:

In urban area, there is one group under strong peri-urbanization and another group of highly urbanized municipalities. The reasons of land abandonment are linked to urbanization. Lands in high risk of abandonment are residual agricultural lands enclosed by urban areas, or between urban area and forests, and lands cut up by extensive constructions and infrastructures. The group under strong peri-urbanization is most concerned by land abandonment. They are mainly composed by municipalities in the New Towns and the pole of Airport CDG. The New Town Marne-la-Vallée is the most significantly concerned area, followed by Evry-Sénart, Cergy-Pontoise and airport CDG. However, the New Town Saint-Quentin-en-Yvelines has no problem of land abandonment driven by urbanization.

In rural area, there is one group highly concerned by land abandonment because of non-urban factors, and another group comprised by the rest municipalities with strong rural characteristics. The reasons of land abandonment are usually linked to poor agronomical conditions such as destruction by sand mining, instability when cultivating wetlands in the valleys, soil pollution, and poor soil quality in the forests area. The highly concerned group is comprised by several benches of Seine and Marne, among which the bench including Triel-sur-Seine and Carrière-sous-Poissy have large area of abandoned lands because of soil pollution by urban waste use.

The dominant reuse of abandoned lands before 1999 was reforestation in rural area and installation of urban open spaces in urban area. After 1999, reforestation and urbanization on abandoned lands both became marginal.

The investigations at local level have studied the perceptions of farmers, habitants, elected representatives and environmental associations about the ecosystem services and disservices of abandoned farmlands. The results suggest differences among the levels of actors and between local areas:

Farmers and habitants at individual level perceive abandoned lands according to their personal experiences, so the knowledge of abandoned farmlands varies widely. The municipal managers, i.e. the mayor, service of urbanism and responsible of associations, have rather an overall image about the location of abandoned farmlands and influences in their municipalities. The managers of the PNR of

Chevreuse are even in a higher level and have the duty to coordinate the interests of different actors including farmers, habitants, and others, working on a wide range of interests.

There are convergences and divergences between the actors in the PNR of Chevreuse and the area of TCV (Triel-sur-Seine, Carrière-sous-Poissy and Vernouillet). Both PNR and TCV recognize the abandoned farmlands as natural and wild spaces, which provide habitats for the wildlife. Such spaces lead to positive feelings, but also bad ones because of the big animals, or the illegal waste dumping and camping. TCV recognizes more the value of abandoned lands in discovering fauna and flora. The PNR does not show a significant interest in the entertainment and esthetic service of abandoned lands. Most of the actors in PNR do not favor the strategy with a pure objective of ecological use. Instead, they would rather support for example agricultural activities combing ecological concerns.

Finally, the hierarchical clustering analysis identified three groups of actors, for which, the determinants are the “Agricultural potentials” (Group 1), “Environmental values” (Group 2), and “Recreational values” (Group 3) of abandoned lands, respectively. Group 1 shows significant willingness for return of abandoned lands to agricultural use. Group 2 would prefer agricultural use for environmental concerns. Group 3 has a high appreciation for entertainment/recreational service of abandoned lands.

Part 3

Multiscale Influences on the Supply-Demand Relationships of Urban Waste Recycling in Peri-urban Agriculture in the Ile-de-France Region

Introduction

The section 2.2.2 of Chapter 3 has analyzed in a general way the sector of urban organic waste recycling in the Ile-de-France Region. There is a long history of recycling urban organic wastes in agriculture in Ile-de-France (Barles, 2005), and the sector is always very important today, especially for sewage sludge and green waste compost. It concerns a balance between the demand for fertilization and the demand for urban waste eliminating. Weight has shift from the side of fertilization to the side of urban waste eliminating in the region (Joncoux, 2013; Dhaouadi, 2014).

The state of Ile-de-France represents a mature stage of the sector because multiple factors and multiple stakeholders interact to improve the system. In developing and emerging countries like Ghana, India, Nigeria, and China, peri-urban farmers take urban organic wastes as important and inexpensive resources for fertilization or irrigation. There is not much concern for the environmental and health risks linked to urban wastes (Keraita and Drechsel, 2004; Liu et al., 2005; Hofmann, 2013). Such practices are harmful to both the side of farmer and the side of city. Problems come just like the history of Achères in Ile-de-France.

As described in Chapter 2, 90% of the regional agricultural lands are occupied by large-sized mechanized cereal and industrial crops, the so called “Grande Culture”. The separation of crop cultivation and livestock since a long time ago led to a lack of organic matter in the soil because of massive use of mineral fertilizers. Urban organic wastes can be very interesting substitutes (Dhaouadi, 2014) for mineral fertilizers, but the most important obstacle is the risk of pathogens or trace elements linked to urban wastes. However, animal manure and mineral fertilizers are also important sources of trace elements in the soil in France (Belon et al., 2012). The environmental and health risk cannot be a reason to exclude urban wastes use, not to mention that the progressively improved regulations ranging from the level of European Union to the regional planning urge the waste producers to limit the risk.

The increasing population and enhanced requirements on waste collecting consequently result in growing needs for urban waste eliminating. Whereas, waste producers can always turn to alternative strategies with the development of new technologies, such as composting and methanation of sewage sludge. According to Chapter 2, farmers in Ile-de-France are in an economic condition which allows more choices of fertilizers, comparing to other countries or regions. Therefore, the farmers and the waste producers are in a seesaw game and there is not an absolute winner.

As a huge metropolitan region, Ile-de-France is in face of the spatial mismatch between the zone of waste production and the distribution of agricultural lands. In peri-urban areas, there is a complicated composition of population because of the urban-rural immigration, and the number of farmers is marginal (see Chapter 2). This population has a variety of concerns, especially for environmental quality and landscape amenity (see Chapter 3). Agricultural recycling of urban waste becomes more complicated than in rural area. The balance between farmers and waste producers is thus under the influences from peri-urban population.

The purpose of this part is to investigate the multiscale influences on the supply-demand relationships of urban waste recycling in peri-urban agriculture in Ile-de-France, with the hope to provide useful suggestions for multiscale management.

This study focus on two urban wastes: sewage sludge and green waste compost. They are the most important urban wastes used in agriculture in Ile-de-France. Furthermore, sewage sludge and green waste compost represent two different channels of waste reclamation, namely, as “waste” or as “product” (Dhaouadi, 2014).

Land application of sewage sludge is in the channel of “waste”. It requires an authorized plan which should define the spreading area based upon an agreement between the sewage sludge producer and farmers. The application should respect the regulations about quantity, time periods, distances to habitation or waterways and others. The commission of the European Communities issued the Directive 86/278/EEC of June 12th, 1986 on land application of sewage sludge, and the French government issued the Decree n°97-1133 of December 8th, 1997 and the Order of January 8th, 1998 to adapt the European directive. These are the fundamental regulations. The sewage sludge producers should deliver annual reports to the authority department to follow up the quality of sewage sludge and the concentration level in the soil of heavy metal components, pathogens and other micropollutants. The sewage sludge producer has responsibility for all pollution incidents and the farmers bear no expenses in the whole process. Such organization was established from 1990s with the rise of concerns for pollution risks.

The green waste compost, to the contrary, has a status of “product” as soil fertilizer or amendment. The legislation has four requirements on these products: effective for the plants or soil, harmless to animals and environment, stable in terms of quality and making reference to an official technical document (Chauvin, 2004). The green waste compost gets the permit for sales based upon two conditions: (i) licensing or a provisional authorization for sale or import (APV or API) delivered by the Ministry of Agriculture and (ii) conformance to standards of French decrees and European directives, i.e. NFU 44-051 for green waste compost since 2006 and NFU 44-095 for the co-compost of sewage sludge with green waste since 2004. The composition of products and the instruction for their use should be marked on the package of products.

The responsibility for pollution incidents is transferred to the users once the co-compost of sewage sludge and green waste is sold in the markets. Therefore, the status of sewage sludge changes between “waste” and “product” depending on the reclamation strategy of wastewater treatment stations.

This study adopts a multi-level approach: a spatial analysis on the regional pattern of the relations between the demand and supply side, and investigations on the local perceptions of different stakeholders regarding agricultural recycling of sewage sludge and green waste compost. It reveals the multiscale influences on the supply-demand balance of sewage sludge and green waste compost by combining the results of the regional pattern analysis and the interviews at two local sites.

The regional pattern analysis of the supply-demand relationship is carried out only on the land application of sewage sludge. The clients of green waste composts include landscapers, farmers and gardeners. Use of the composts has few constraints once sold. Land application of sewage sludge mainly relies on “Grande Culture” and is forbidden in organic farming and vegetable cultivations. Its application is strictly controlled by detailed regulation. It is possible to get information about the origins of wastewater and the distribution of suitable agricultural lands. Therefore, it is more meaningful and practicable to analyze the spatial pattern for land application of sewage sludge, comparing to green waste compost or the co-compost of sewage sludge.

This part includes two chapters. Chapter 6 describes the study area and methodology, and Chapter 7 presents the results.

Chapter 6

Materials and methodology of the study on agricultural recycling of urban wastes in the Ile-de-France Region

1. Study area and selection of local study sites

1.1. Study area

(1). Sewage sludge production and application in Ile-de-France

In Ile-de-France, wastewater is collected and treated either by collective or individual sanitation systems. Collective sanitation is the dominant form. When massive volume of wastewater is treated together, the outlets of sewage sludge can be a problem. Individual sanitation systems only exist in remote rural areas where collective sanitation is not effective. Wastewater treatment plants are the basic elements of collective sanitation systems.

Fig.6-1. shows the distribution of 462 plants that are in normal working conditions from 2010 to 2013 in Ile-de-France according to the Municipal Sanitation Information Portal System of the Ministry of Ecology, Sustainable Development and Energy (MEDDE). The plants are in constant dynamic, such as expansion or upgrading of old plants, and opening of new plants. The four year data may offer a relatively stable image about the regional sanitation capacity. Important plants not mentioned in the map are the one of Ollainville, opened in 2011, and Montereau-confluent upgraded from 8000 PE to 20000 PE. PE is the abbreviation for Population Equivalent. It assumes that the sewage produced by one person during 24 hours equals a pollution load of 60 grams of BOD5. The five-day-Biochemical Oxygen Demand (BOD5) is the amount of dissolved oxygen needed by aerobic biological organisms to breakdown the organic material in the sewage during five days.

The SIAAP (Interdepartmental Syndicate for the Sanitation of the Parisian Agglomeration) has the biggest system in Ile-de-France. It provides sanitation service to 331 municipalities, including Paris, the whole of the three departments in the inner suburb, namely, Hauts-de-Seine (92), Seine-Saint-Denis (93), and Val de Marne (94), and 187 municipalities of the outer suburb in Seine-et-Marne (77), Yvelines (78), Essonne (91) and Val-d'Oise (95). The wastewater of SIAAP is treated by six plants, including, (i) Marne Aval in Noisy-le-Grand (Seine-Saint-Denis), (ii) Seine Aval located in Achères, Maisons-Laffitte and Saint-Germain-en-Laye (Yvelines), (iii) Seine Grésillons in the Triel-sur-Seine (Yvelines), (vi) Seine-Amont in Valenton (Val-de-Marne), (v) Seine-Centre in Colombes (Hauts-de-Seine) and (vi) Seine-Morée in Le Blanc-Mesnil (Seine-Saint-Denis). Seine-Morée is opened in 2014, so not considered in this study.

The distribution of wastewater plants is opposite to the distribution of population in terms of number but matches the distribution of population in terms of capacity. Urban area with high population densities is covered by a few big plants managed by intermunicipal sanitary organizations.

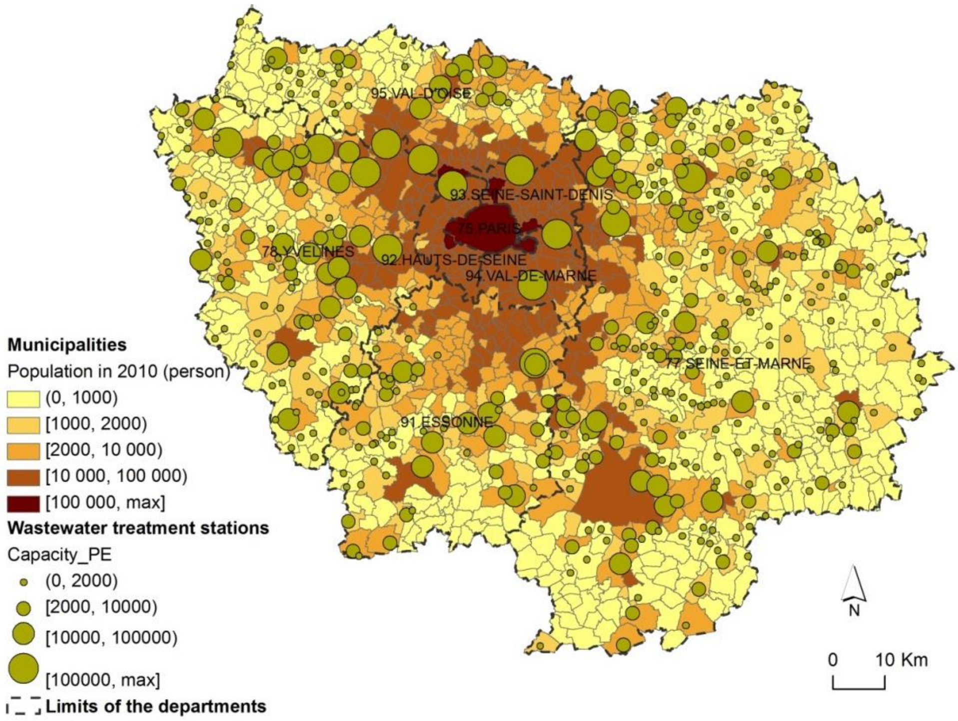


Fig. 6- 1. Location of 462 water treatment stations in normal working conditions from 2010 to 2013 in Ile-de-France. Data for the map was from the Municipal sanitary information portal system of the Ministry of Ecology, Sustainable Development and Energy and INSEE.

The wastewater plants of different capacity levels adopt different types of treatment processes. According to the Observatory on Water of the General Council of Seine-et-Marne, there are mainly 8 types of treatment processes (Fig. 6-2). Sand filters, filters planted with reeds, bacterial bed, lagoon and rotating biological contactor exist in the small plants, normally of less than 2000 PE. Sludge is extracted only once during several years. The outlet of sludge is not a big problem for these plants. Activated sludge system, membrane filtration and biofiltration are more adapted to highly urbanized area and big plants.

The sewage sludge then may have different forms depending on complementary treatments, which includes liquid, dewatered, dewatered and limed, and thermally dried sludge (see Section 2.2.2 of Chapter 3 for detailed agronomic characteristics of these different forms). Fig. 6-3 illustrates the final land application process of liquid sludge and solid sludge.

The process from wastewater treatment to land application of sewage sludge may be managed by the municipality, or an intermunicipal syndicate for sanitation, but it is also possible that the sanitation syndicate delegates the service to a professional enterprise. The enterprise of wastewater treatment then again can delegate to another company the work of treatment and outlet of sludge. Incineration, composting, methanation, landfilling and industrial destinations are alternative outlets of sewage sludge.

Sand filters (Forges, 110 PE)

Filters planted with reeds (Cemeux, 250 PE)

Bacterial bed (Mauperthuis, 500 PE)

Lagoon system (Chevru, 600 PE)

Rotating biological contactor
(Saints, 900 PE)

Activated sludge system
(Provins, 23 330 PE)

Membrane filtration
(Perthes-en-Gâtinais, 4500 PE)

Biofiltration
(Saint-Thibault-des-Vignes, 350 000 PE)

Fig. 6- 2. Different wastewater treatment systems in Ile-de-France. Source: Observatory on Water of the General Council of Seine-et-Marne, 2010a.

Fig. 6- 3. Agricultural land application of sewage sludge. a. liquid sludge, b. solid sludge. Source: the site of Valterra, an enterprise specialized in agricultural reclamation of urban waste

(2). Green waste compost and co-compost in Ile-de-France

Fig. 6-4 presents the distribution of 37 platforms of green waste-compost in Ile-de-France. Most of them are private platforms, locate on the periphery of the central agglomeration and have small or medium capacity. Fig. 6-5 illustrate the processes of composting taking one platform in Saclay as an example.

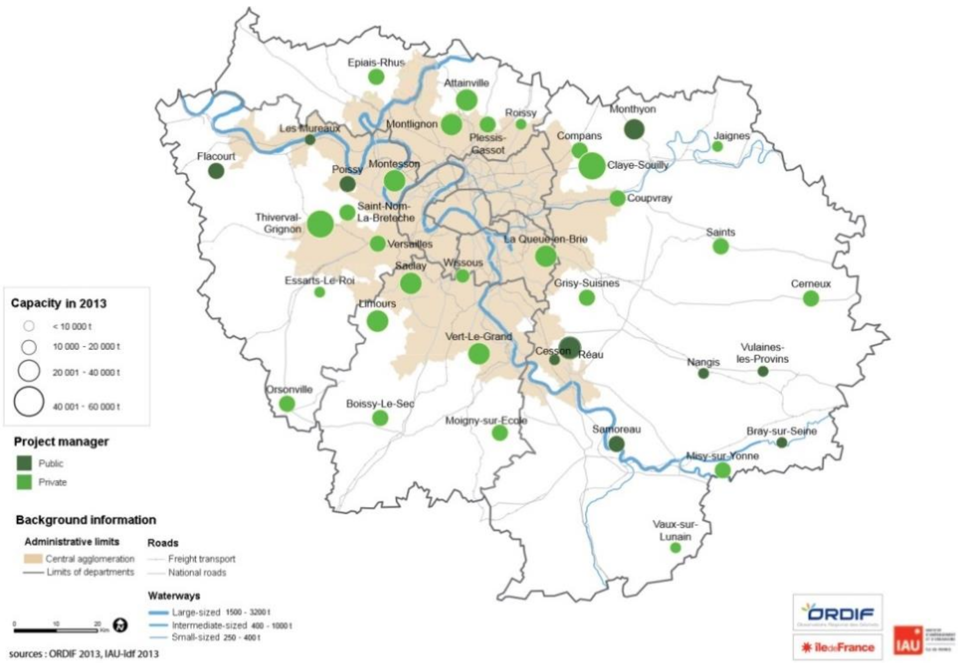


Fig. 6- 4. Location of green waste compost platforms in Ile-de-France. Source: ORDIF, 2014

Fig. 6- 5. Processes to make green waste compost. Source: the website of a green waste compost platform called "Ferme de La Martinière" in Saclay of Ile-de-France.

1.2. Selection of two local study sites

The Plaine de Versailles and the Plateau de Saclay are the two local sites selected for interviews with different stakeholders. The two areas are both located about 20 km to the West of Paris (Fig. 6-6). The west part of Ile-de-France has the strongest awareness of environmental quality and resistance to urban expansion. Meanwhile, the west part has stronger urban characteristics compared to the rural department of Seine-et-Marne in the east.

The Plaine de Versailles was called "the valley of Gally". Its eastern part is adjacent to the Park of Versailles and thus was the former hunting area of the French kings. The Heritage Association of the Plaine de Versailles and the Plateau des Alluets (APPVPA) was created following the concern over the classification of 2600 ha of lands as a zone for protecting natural and historical heritage in 2000. The objective of this association is to protect the dynamic and development opportunities of agriculture by improving the cooperation between farmers and residents in this peri-urban area.

Plateau de Saclay has been dedicated to a national research and technology center since 1949. It is an agricultural zone almost enclosed by the Paris agglomeration, Ville-Nouvelle of Saint-Quentin-en-

Yvelines and the Regional Natural Park of Chevreuse. This area is within an Operation of National Interest (OIN) from 2005 and a number of projects have ambitious plans for it, e.g. a new urban sub center, a scientific cluster and the project of "Grand Paris". The association "Terre & Cité" (Land and City) was created in 2001 for the purpose to coordinate different stakeholders in Plateau de Saclay in order to protect agricultural lands against the invasion of urbanization projects. A zone of 2300 ha for protecting nature, agriculture and forest has been finally reserved.

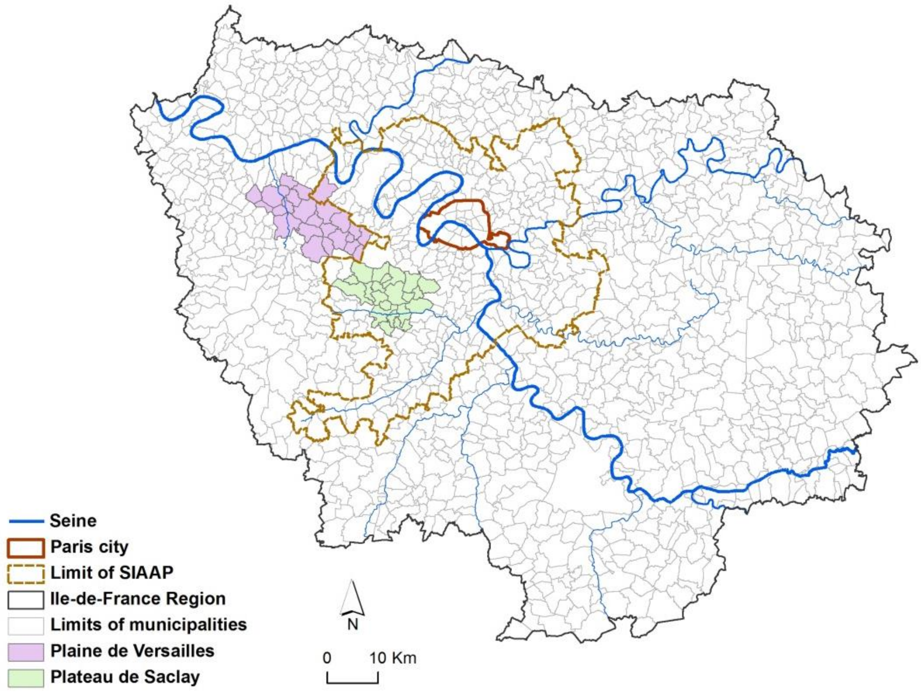


Fig. 6- 6. Location of two local study sites

Thus, the Plaine de Versailles and the Plateau de Saclay are two zones of agricultural protection in peri-urban area, the former against being frozen for natural or cultural interests while the latter against urbanization. Both areas are working on cooperation among different stakeholders and trying to build territorial cohesion based upon development of multifunctional agriculture. The two cases are representative for anticipating the future of big metropolitan regions where environment, agricultural, ecological and urban concerns intertwine.

According to APPVPA and "Terre & Cité", the Plateau de Saclay is smaller than the Plaine de Versailles and has a higher population density than the latter (1265 p/km^2 v.s 700 p/km^2). In Plateau de Saclay, agricultural lands represent 17% of the total area while in the Plaine de Versailles, the proportion is 45%. The Plaine de Versailles has 8 wastewater treatment plants and 2 green waste composting platforms. Plateau de Saclay has one green waste composting platform and a small wastewater treatment plant (1100 PE, Saclay). Most of its wastewater is collected by SIAAP and treated in the plant of Valenton.

2. Methods to analyze the regional pattern of supply-demand relationships of sewage sludge land application

For the reason to avoid too much uncertainty when there is limited data, this study did not realize a regional map of the balance between the amounts of supply and demand for land application of sewage sludge.

For the side of sewage sludge production, I investigated the regional pattern regarding the quantities of sewage sludge produced and the part used for land application. The collecting zones of sewage plants are analyzed to identify the origins of wastewater

Then for the demand side, I investigated the municipalities with important potential to take sewage sludge for land application, based upon the area of agricultural lands and requirements of the regulations.

After that, the supply side and demand side of sewage sludge are compared and discussed through two analyses. The first is to examine the spatial flows of sewage sludge for land application in Seine-et-Marne in 2009. The second is to estimate the crop succession pattern of “Grande Culture” in Ile-de-France because crop succession is the most important determinant of sewage sludge use when the lands have suitable physical conditions.

2.1. Regional pattern of sewage sludge production

The records of wastewater plants in Ile-de-France were from the Municipal Sanitation Information Portal System (Portail d'information sur l'assainissement communal) of MEDDE. This database has detailed annual information of each wastewater plant in France from 2009 to 2013, covering the basic characteristics, amounts of waste water treated, sludge production, as well as the quantities of sludge towards different outlets. According to the capacity of plants, they can be classified into four grades: <2000 PE, 2000-10000 PE, 10 000-100 000 PE, and >100 000 PE. The data for the plants <2000 PE may be incomplete or inaccurate.

I first identified the plants that had a same capacity or at least remained in the same grade through the period from 2010 to 2013. This is for the purpose to get a relatively stable image of the regional pattern because it’s hard to get a fixed number and every year there are some plants in extension, upgrading or abandonment. This step can also guarantee that the plants in analysis were in normal working conditions through this period. The data of 2009 missed a lot of records comparing to the following years. That’s why the time period was set as 2010-2013. This process resulted in 462 plants, and Fig. 6-1 shows their location.

Then, I accumulated the amount of sludge productions during 4 years (2010-2013) for each plant. This is because fluctuation between years for accidental reasons can largely influence on the production of plants, and thus result in inaccuracy in the assessment of regional pattern. Similarly, I summed up the amounts of sludge used for agricultural land application from 2010 to 2013 for each plant.

Third, I tried to identify the collecting zones of the wastewater plants that produced more than 1000 t Dry Matter (DM) sewage sludge (Qp) or sent more than 1000 t DM sludge to agricultural land application (Qa) from 2010 to 2013. These two categories of plants represented 94.4% of the regional production and 90.5% of the land application of sewage sludge, respectively. A variety of documents and websites were referred to find out the information about the collecting zones. Furthermore, combination of the two criteria (Qp > 1000 tDM, Qa > 1000 tDM) resulted in four categories of plants. The mapping was carried out in ArcGIS 10.0.

2.2. Distribution of suitable agricultural lands for sewage sludge application

Combining the distribution of agricultural lands and requirements of regulations allows identifying the municipalities with important potential regarding land application of sewage sludge. The Graphical Land Parcel Registration (RPG) is the base to build up an authorized plan for land application. RPG was set up in France following the regulation of European Community (EC) n°1593/2000 requiring the location and identification of agricultural parcels in all the Member States. It is managed by the Agency of Services and Payments (ASP) and updated annually. RPG is managed in the Geographical Information System. The coordinate system adopted is Lambert 93. The location of land parcels was drawn on a map scale of 1:5000. Each object represents a land parcel or a group of parcels, carrying the code of crop types and the area of each crop type when there are more than one crop types. The data available for this study are from 2006 to 2010.

The limits in regulations for sewage sludge application concern the slop, and the distance to rivers, water area, habitation, and potable water production sites. Fig.6-7 presents the distribution of these features. The municipal suitable area for sewage sludge application was assessed following three steps:

2.2.1. Identification of lands of "Grande Culture"

In Ile-de-France, land application of sewage sludge mainly relies on the system of "Grande Culture". The first step is to select the parcels of Grande Culture. Grande Culture systems normally cultivate a few crop types in a large land parcel of 20 up to 100 ha. The "Specialty Crops" like vegetable cultivation, fruits, flowers and wines occupy small parcels less than 5 ha and have a high diversity. It's possible to divide the two systems with the ratio "number of crop types per hectare" (Nc/ha).

It was easy to calculate this ratio with RPG and the following task was to find out the threshold that approximates the boundary between Grande Culture and Specialty Crops. Analysis in Chapter 2 has revealed that the system of Grande Culture is practiced separately from the systems of Specialty Crops. Thus, when the ratio Nc/ha fluctuates between the years following the crop succession in Grande Culture, it will not pass that threshold. Meanwhile, the lands of Grande Culture should be stable in the period from 2006 to 2010 in Ile-de-France. Therefore, I calculated the sub-total areas of land parcels with different value on "number of crop types per hectare" (Nc/ha= 0.01, 0.02, 0.03…until 0.5) for every year from 2006 to 2010. Then, I compared the curves of sub-total area along the value of Nc/ha between the different years. The curves fluctuate in the interval 0.04-0.08 and the interval 0.12-0.25 of Nc/ha (Fig. 7-3 in Chapter 7). Thus, the analysis suggested an approximation of the threshold as >0.255 to remove the lands of Specialty Crops. I did that on RPG 2010. It turned out that the lands being removed were small-sized and mainly located in the valleys.

After that, I also removed the lands with the following main crop types: heathland, permanent prairies, fruits, wines, nuts, olives, vegetable and flowers, sugar cane, arboriculture and others. These crop types are not in the system of Grande Culture according to Chapter 2.

2.2.2. Considering the limitation of regulations

The limits of regulations are mainly about the different isolation distances imposed by the European Nitrate Directive and the French Order of 1998. Land application of sewage sludge should keep a distance of 100 m to habitations, 35 m to water area and rivers when slop < 7%, or 200 m when slop >7%, and 100 m to the area linked to portable water extraction and production. The slope was calculated using the spatial analysis tool set in ArcGIS 10.1from Digital Elevation Data (ASTER GDEM 30 m) of Ile-de-France Region. As the lands with slop < 7% and > 7% closely mixed in the agricultural area, which are principally located on the plateaus, the distance of 200 m to rivers and water area was adopted.

The vector data of hydrology networks came from IAURIF (Institute of Management and Urbanism of Ile-de-France), but I removed the streams with a flow accumulation zone smaller than

18km^2. The selection was realized by comparing the data of IAURIF with the stream links obtained from the "Hydrology" analysis in ArcGIS. The Digital Elevation Model data came from the ASTER GDEM (30m). The threshold value of flow accumulation was set as "20000" to build stream links. The location of individual and collective habitation, water area and potable water production were from the land use database MOS of IAURIF.

The "Buffer" tool and "Erase" tool of ArcGIS helped to cut off the agricultural lands within the distances as described above.

Then, I removed tiny polygons or polygons with a strange shape. These lands are not suitable for land application of sewage sludge because they are difficult to access by trucks. After the operation of "Explode Multi-part Feature", the ratio of Area/Perimeter of each polygon that remained was calculated. A final selection removed the polygons in the following three cases: (i) Area < 1 ha, (2) Area < 10 ha and the ratio Area/Perimeter < 30, (3) Area >10 ha and the ratio Area/Perimeter < 50. These criteria were defined by examining the polygons being selected.

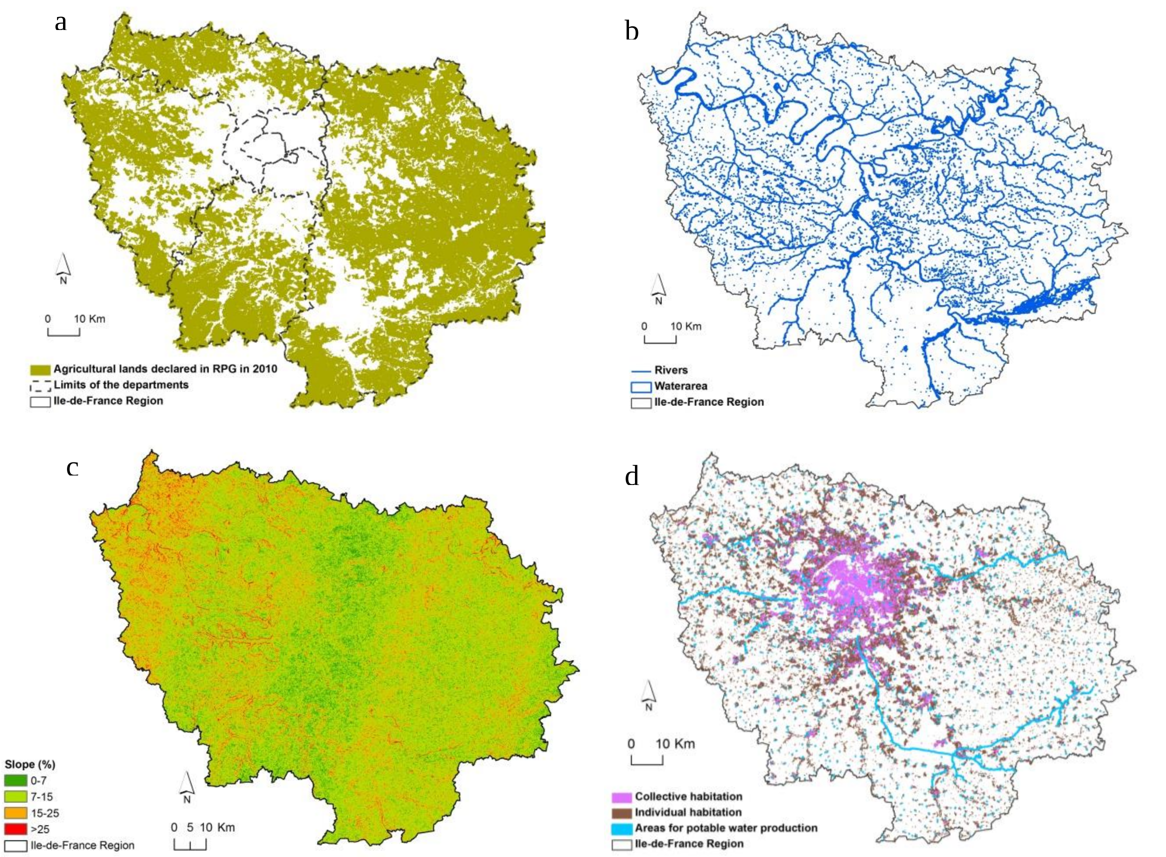


Fig. 6- 7. Features for the identification of agricultural lands suitable for application of sewage sludge. a. Graphical Land Parcel Registration (RPG), b.water area and rivers, c. slop d. water production and habitation.

2.2.3. Municipal potential for land application of sewage sludge

The municipal potential is defined by the area of suitable lands obtained by the above procedures in each municipality. The area was calculated by the tool "Attribute Area" of ArcGIS. Landscape matrix Aggregation Index (see Chapter 4, Section methodology) was calculated at municipal level in Fragstat to examine the spatial structure of the selected agricultural lands. Aggregation Index helped to identify the municipalities that had almost no suitable agricultural lands but share a fringe of farmlands of adjacent neighbors. In the rest of municipalities, the selected agricultural lands all have a good aggregation level (AI >87.9).

2.3. Spatial flows of sewage sludge through land application in Seine-et-Marne

The Observatory on Water of the General Council of Seine-et-Marne (2010b) published a study on 659 land parcels on which sewage sludge or settling tank sludge was applied in 2009 in Seine-et-Marne. This report released detailed information about the origins of the sludge, land area, date of application, crop types, quantity of application and others at the parcel level. I extracted the 599 records of sewage sludge application for the analysis of the spatial flows from wastewater plants to agricultural lands.

The analysis for connecting the supply side and demand side overlaid the distribution of the collecting zones of wastewater plants with that of the municipalities receiving the sludge. The distribution of suitable lands was also used as a background value.

2.4. Estimation on crop succession pattern in Ile-de-France

Crop succession and crop rotation are terms introduced into France in late 18th century (Morlon, 2013): crop rotation is a cycle or round of crops that recur in the same order on a field, repeatedly; when farmers do not practice a complete cycle, the term “crop succession” would be more appropriate. A particular crop succession implies particular practices and time table. The dissertation of Dhaouadi (2014) revealed that crop succession significantly influences on agricultural use of organic wastes. Especially, rape is commonly used as the head of succession, and a crop most favored for sewage sludge application.

As no long term data is available, crop succession pattern of “Grande Culture” in Ile-de-France was estimated based upon RPG of 5 successive years: 2006, 2007, 2008, 2009 and 2010. Farmers declared the crop type on a land parcel or several crop types on a group of land parcels each year. Only the parcels having one crop type in every year are selected for the analysis on crop succession. These parcels accounted for 27.8% of the total area of RPG in 2010. Their location in the regional agricultural lands (Fig. 6-8) suggested that the analysis on these parcels can be instructive for understanding the regional pattern.

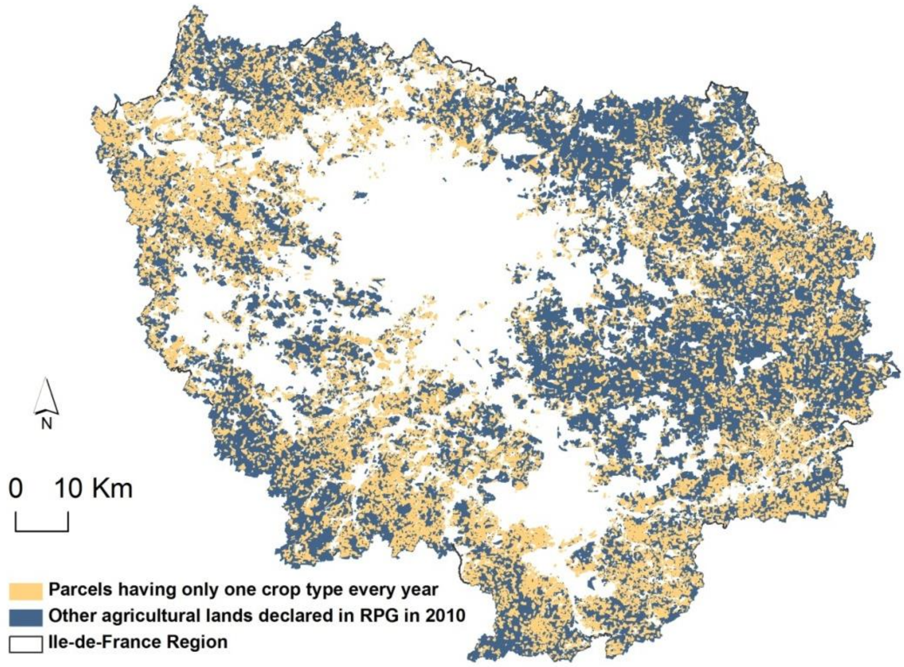


Fig. 6- 8. Parcels with only one crop type every year selected for analysis on crop succession

(1). Preparing the time serials of crop types

First, the parcels with only one crop type in every year were extracted to separate shapefiles in ArcGIS. The shapefiles of 5 successive years were intersected following time order, so they were integrated into one shapefile and each polygon carry a serial of codes corresponding to crop type in the years from 2006 to 2010, successively. The tool of "Calculating Geometry" allowed getting the area of each polygon. Then the attribute table of this shapefile was imported into Excel 10.0 for the following analysis on succession types.

(2). Regrouping the crop types into 9 categories

Considering that the target is to analyze Grande Culture, I reclassified 28 crop types of RPG into 9 types: 1. wheats, 2. corns, 3. barleys, 4. other cereal crops, 5. rapes, 6. protein crops, 7. fallow lands, 8. other industrial crops, 9. other various crop types. The type 8 industrial crops includes sunflowers and other oil crops, fiber plants, and also the "Gel Industriel" as called in French, which means the lands temporally withdraw from cereal cropping and are cultivated for industrial destinations. The type 9 other various crop types includes seeds, grain legumes, forages, heathland, permanent prairies, temporal prairies, fruits, wines, nuts, olives, vegetable and flowers, sugar cane, arboriculture and others. The polygons with an area less than 0.1 ha were removed. Those tiny polygons may be only the results of the intersection procedure because of the shift of field margins.

(3).Computing and interpretation of succession trajectories

Succession trajectories were computed according to Equation 1 (Wang et al., 2012). Polygons that have a same code from 2006 to 2010 were removed to a separate file as areas of mono-cultivation.

$$T_i = (G1)_i \times 10^{n-1} + (G2)_i \times 10^{n-2} \cdots + (Gn)_i \times 10^{n-n} \qquad (1)$$

T_i is the trajectory code of the polygon *i*; *n* is the number of time nodes, and *n*=5 in this study; *G1*, *G2*, …, and *Gn* are the codes of crop types of polygon *i* in year 1, year 2, …, and year *n*.

Interpretation of succession types was realized using the functions of Excel for (i) calculating the number of different crop types appeared in each polygon during this period (n=2, 3, 4, 5), (ii) area statistics of the different combination of crop types in each polygon without distinguishing the order and number of recurring of each crop type, (iii) area statistics on the trajectories considering time order and number of recurring for the most important categories identified by (ii). The results were reimported into ArcGIS to visualize the spatial pattern of crop succession.

3. Interviews and analysis on multiscale influences on the supply-demand relationships

An analysis on multiscale influences on the supply-demand relationships then was carried out based upon interviews with different actors in two local areas, the Plaine de Versailles and the Plateau de Saclay (Fig.6-6).

The interviews include three phases: 6 interviews in 2012-2013 for a global image of the waste recycling industry, 17 interviews in 2014 by Apolline Boissau with local actors and 8 in 2014-2015 by Clément Jaffré as complements. The analysis also integrated the notes of 12 interviews of Karim Dhaouadi (Dhaoudi, 2014), carried out in 2009-2011 in the Plaine de Versailles for his PhD program.

The interviews covered different categories of actors:

(1). Waste producers

This category includes 4 sanitation syndicate (SMAROV-the plant of Carré de Réunion, SIEARPC-the plant of Plaisir, SIAVGO- the plant of Villepreux, Thi-Feu-Cha- the plant of Thiverval), 1 company delegated manager of public service of wastewater treatment (SEVESC), 3 intermediate companies for the management of sewage sludge and other wastes (SEDE, Thérralys, Valterra), 3 platforms of green waste compost (BioYvelines, a platform in Saint-Nom-la Brétèche, a platform in the Plateau de saclay), 1 equestrian center and 1 canteen manager who produced bio-waste in Plateau de Saclay.

(2). Farmers

The analysis includes 15 farmers in the Plaine de Versailles and 3 in the Plateau de Saclay. All were in the system of “Grande Culture” of wheat, rape, corn, barley and fava beans. Most of them had between 200 and 300 ha farmlands. One of them also worked on vegetable cultivation besides cereal crops. 2 farmers were doing organic farming. We selected these farmers who are in a variety of situations and thus may have different attitudes towards urban waste use. They are also representative of the agricultural activities in the two sites.

(3) Municipal representatives of habitants

This category includes the former mayor of Plaisir and the responsible of the Agglomeration Community (Communauté d’Agglomeration) of Versailles Grand Parc.

(4) Regulation makers

This category includes the Direction Départementale des Territoires (DDT) of Yvelines, and the Regional Observatory on Wastes of Ile-de-France (ORDIF).

(5) Other actors

We also met the responsible in the Chamber of Agriculture of Ile-de-France, APPVPA and Terre & Cité, the two associations dedicated to territorial cohesion in the Plaine de Versailles and the Plateau de Saclay, respectively (see section 1.2 for their roles), and two researchers working on this subject (Karim Dhaouadi and his PhD supervisor Dr. Houot).

Each interview lasted from 30 minutes to 2 hours in the form of free conversation guided by a questionnaire. The questions include first the general information of the actor, for example, the area of agricultural lands, soil types, crop succession and land tenure of a farmer, technology and the commercial system of the sanitation service. The second part of the questions is about the actors' practices, for example, a farmer uses or not the sewage sludge or green waste compost, how (quantity, periods, equipment, transportation, storage…) and why (perceptions of benefits and negative impacts, relations with the neighbors…). As for the waste producers, the questions include their choices of strategies for the evacuation of sewage sludge or green waste, the problems linked to agricultural recycling (transportation, storage, and relations with farmers…). The last part is about their perspectives for the future of agricultural recycling of urban wastes. The Appendix 11 and 12 present the questionnaires for interviews with farmers and waste producers, respectively.

Full transcription was made for most of the interviews. Apolline Boissau (Boisseau, 2015) and Clément Jaffré did a first analysis on these interviews. Based upon all these materials and reference documents (e.g. the European directives, French laws and others), I built a framework about the factors at multiple scales that influence on the supply-demand relationships regarding agricultural use of urban wastes (sewage sludge and green waste compost). At last, I analyzed the different categories of farmers according to their practices and perceptions of urban wastes use.

Chapter 7

Results of the study on agricultural recycling of urban waste in the Ile-de-France Region

1. Regional pattern of supply-demand relationship of sewage sludge for land application

1.1. The side of sewage sludge production in Ile-de-France

1.1.1. Statistics of the production and outlets of sewage sludge

(1). Production of wastewater plants

As table 7-1 shows, the 13 biggest plants (>100 000PE) account for 87.5% of the regional total capacity of wastewater treatment. They provide service to 87.4% of the regional population engaged in collective sanitation. Sewage sludge produced by these plants represented 84.2% of the regional quantity in 2013, and the proportion reached 96.4% together with the 54 plants in the secondary grade (10 000-100 000 PE). Therefore, recycling of sewage sludge is mainly a problem of the big plants in Ile-de-France.

Table 7- 1 Basic characteristics of wastewater plants in Ile-de-France in 2013

Capacity grades	Number of plants		Capacity		Population size	
	N	Per. %	PE	Per. %	PE	Per. %
>100 000PE	13	2.8	14 645 916	87.5	11 328 420	87.4
10 000-100 000PE	54	11.7	1 481 216	8.8	1 208 808	9.3
2000-10 000PE	98	21.2	408 902	2.4	298 666	2.3
<2000PE	297	64.3	205 470	1.2	118 940	0.9
Regional sum	**462***	**100**	**16 741 504**	**100**	**12 954 834**	**100**
Capacity grades	Average inflow	Sewage sludge production		Average time of storage	Possession of authorized plan for land application	
	m^3/day	tDM/year	Per. %	Months	Number	Rate %
>100 000PE	209 282	141 577	84.2	1.8	9	69.2
10 000-100 000PE	3 636	20 467	12.2	3.3	35	64.8
2000-10 000PE	572	4 185	2.5	3.6	61	62.2
<2000PE	102	1987	1.2	1.5	127	42.8
Regional sum/average	**6 501**	**168 216**	**100**	**2.2**	**232**	**50.2**

*Plants in normal working conditions through the period of 2010-2013.

9 plants with a capacity > 100 000 PE have an authorized plan for land application, accounted for 69.2% of this grade. This rate is 64.8% in the grade 10 000-100 000 PE, and 62.2% in the grade 2000-

10 000 PE. So the rate does not differ too much among different grades. Plants with a capacity < 2000 PE do not necessarily need an authorized plan for land application, and the rate is only 42.8%. At the regional level, half of the plants have an authorized plan for land application. Wastewater plants usually need to store sewage sludge for a certain period to wait for land application or other treatment. Storage of sewage sludge is potentially problematic because of cost rising or complaints from neighbors. The biggest plants that produce the most important amounts of sewage sludge need less time for the storage, contrary to what one might expect. The smallest plants do not produce much sludge regularly, so the problem of storage is not significant.

(2). Outlets of sewage sludge

The outlets of sewage sludge for an individual plant include agricultural land application, incineration, composting to get the status “products”, landfilling, being processed into materials for industrial use, being sent to other plants. Land application includes also the compost of sewage sludge that remains in the status “wastes”. Table 7-2 presents the proportions of sewage sludge into different outlets from 2010 to 2013. The quantity here is measured with dry matter weight.

Table 7- 2 Proportions of different outlets of sewage sludge from 2010 to 2013

Capacity grades of plants	Year	Proportion of different outlets (%)						Total quantities (t DM)
		Agricultural land application*	Incinera-tion	Composting into “produt”	Landfilling	Industrial use	Sent to other plants	
>100 000 PE	2010	57.9	30.9	2.4	0.0	8.8	0.0	103 673
	2011	36.1	30.2	21.4	5.7	6.5	0.0	148 277
	2012	32.6	34.6	20.3	2.0	10.6	0.0	160 755
	2013	40.5	26.5	23.8	4.8	4.3	0.0	126 042
10 000-100 000 PE	2010	77.2	7.1	14.0	0.5	1.1	0.0	18 385
	2011	61.8	5.8	17.4	2.3	1.2	11.6	19 173
	2012	51.1	15.6	21.7	2.5	1.3	7.9	18 301
	2013	45.8	17.5	29.0	2.8	0.0	4.9	17 600
2000-10 000 PE	2010	66.0	7.4	5.3	1.3	0.0	20.0	4 001
	2011	61.0	8.4	6.9	2.1	0.0	21.5	4 503
	2012	66.2	7.4	11.0	2.8	0.0	12.6	3 629
	2013	60.7	9.3	13.8	1.8	0.0	14.6	3 919
<2000 PE	2010	69.6	6.3	8.8	6.5	0.0	8.8	1 014
	2011	63.3	3.4	7.7	4.0	0.0	21.6	1 443
	2012	74.1	5.5	8.5	1.6	0.0	10.3	1 750
	2013	73.6	5.4	8.0	1.3	0.0	11.7	1 893
Regional sum	2010	61.5	26.7	4.3	0.2	7.4	-	126 185
	2011	40.7	27.3	20.9	5.3	5.9	-	169 895
	2012	35.9	32.2	20.4	2.1	9.4	-	182 356
	2013	42.5	25.0	24.2	4.5	3.7	-	147 792

*including compost that remained in the status “waste” and was used for land application.

Agricultural land application was the most important outlet, especially for plants in smaller capacity grade. The proportion of agricultural land application increased for the grade of capacity < 2000 PE from 69.6% in 2010 to 73.6% in 2013 as a substitute for landfilling. Contrarily, this proportion decreased progressively for the grade of 10 000-100 000 PE because of the rise of incineration and composting. As for the grade of 2000-10 000 PE, the percentage of land application fluctuated between different years, but the proportion of composting increased stably. The biggest plants (> 100 000 PE) had more diversified strategies and the proportion for land application was the least among the four grades of plants. Incineration and composting also took up an important percentage. The choice of industrial destination was only practicable for the biggest plants. However, since the biggest plants had significant level of sewage sludge production, they are still the primary supplier of sewage sludge for land application.

1.1.2. Spatial pattern of sewage sludge production

(1). Four categories of wastewater plants

The wastewater plants were distinguished into 4 categories based upon whether the 4-year (sum of the period from 2010 to 2013) sewage sludge production (Qp) or land application (Qa) is higher than 1000 tDM. Fig. 7-1 presents their spatial pattern.

The first category (Qp > 1000 tDM and Qa > 1000 tDM) includes 21 plants, among which are 2 plants of SIAAP, the Seine-Aval in Achères and the Seine-Amont in Valenton. Seine-Aval output 76.7% of sewage sludge to agricultural land application, 12.8% to composting, 5.3% to landfilling and 5.1% to industrial use. Seine-Amont output 5.8% of sludge to land application, 33.8% to incineration, 36.4% to composting, and 23.9% to industrial use.

The second category (Qp < 1000 tDM but Qa > 1000 tDM) includes two plants: Coulommiers and Fontenay-Tresigny. The plant Coulommiers did not have an authorized plan for land application in 2013. This category had more sewage sludge in land application than their sludge production possibly because they received sludge from neighboring plants.

The third category (Qp > 1000 tDM but Qa < 1000 tDM) includes 18 plants. These plants relied more on other outlets of sewage sludge. For example, the other three plants of SIAAP were in this category. Seine-Centre and the Marne-Aval did not output sludge to agricultural land application, and 98.6% and 99.6% of sludge were incinerated, respectively. Seine-Grésillons output 65.5% of sewage sludge to composting, 15.7% to incineration, 14.8% to industrial use and only 4.0% to land application.

The other 421 plants were in the fourth category (Qp < 1000 tDM and Qa < 1000 tDM). They are located in the rural suburbs and predominantly along the hydrological networks.

33 among the 41 plants in the first three categories adopt the “activated sludge” process. 6 plants have the biofiltration process: Seine Aval, Seine-Centre, Marne-Aval, Seine-Grésillons, Lagny-sur-Marne-Saint-Thibault-des-Vignes and the Cergy-Pontoise-Neuville-sur-Oise.

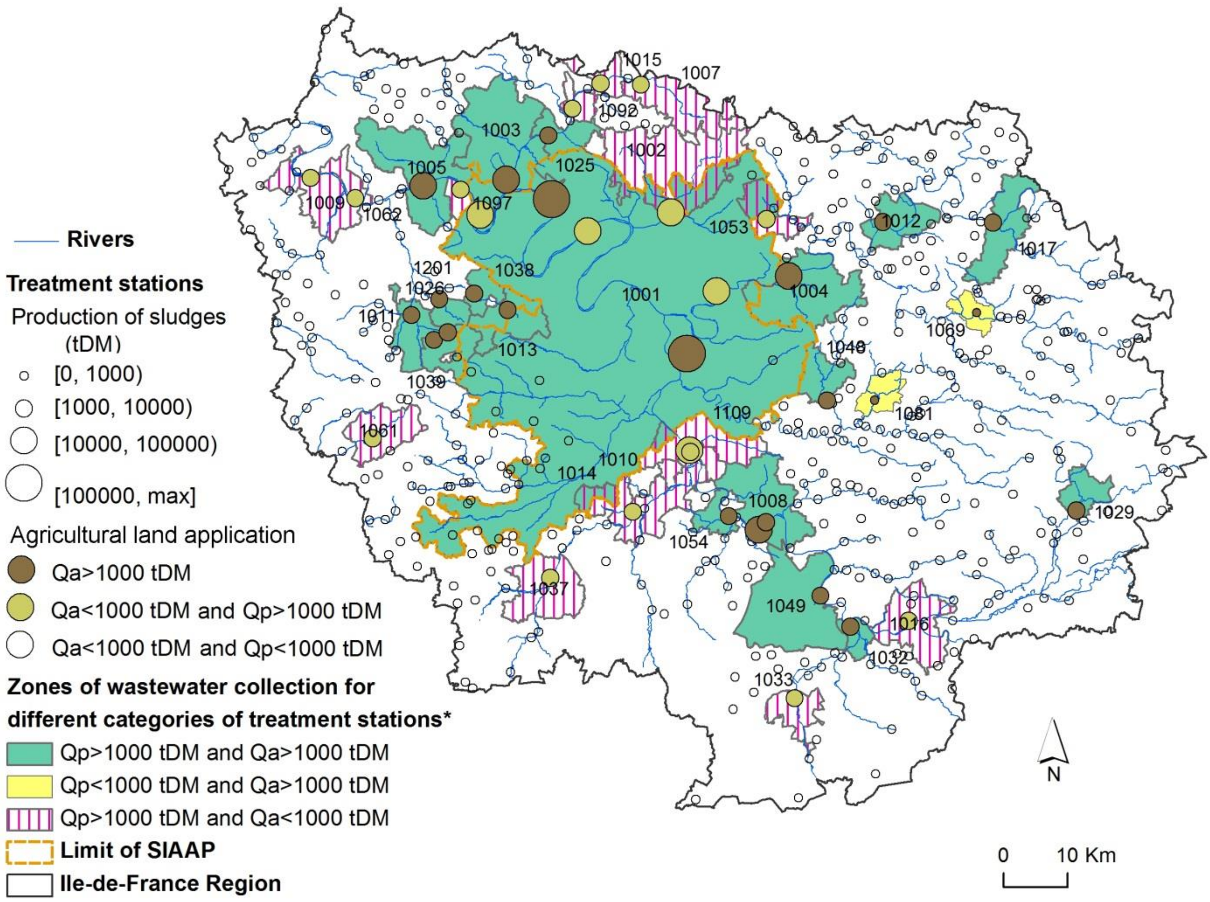


Fig. 7- 1. Spatial pattern of the principal origins of sewage sludge in Ile-de-France. Qp: accumulative quantity of sewage sludge production from 2010 to 2013, Qa: accumulative quantity of agricultural land application from 2010 to 2013. The collecting zones were drawn based upon the municipal limits though sometimes only one part of a municipality was covered by the service of a certain plant. That also explained the overlap in the map. *The numbers in the map signify the code of the collecting zones of the corresponding wastewater plants: Category 1 "Qp > 1000 tDM and Qa > 1000 tDM": 1001. SIAAP, 1003. Cergy-Pontoise-Neuville-sur-Oise, 1004. Lagny-Sur-Marne-St-Thibault-des-Vignes, 1005. Les Mureaux, 1008. Dammarie-Les-Lys and Boissettes, 1011. Villiers-Saint-Frédéric, 1012. Meaux, 1013. Carré-de-Réunion, 1017. Sept-Sorts, 1025. Auvers-sur-Oise, 1026. Elancourt, 1029. Provins, 1032. Veneux-Les-Sablons, 1038. Villepreux, 1039. Maurepas, 1048. Presles-en-Brie, 1049. Fontainebleau-Avon, 1054. Saint-Fargeau-Ponthierry, 1201. Le-Val-des-Eglantiers. Category 2 "Qp < 1000 tDM and Qa > 1000 tDM": 1069. Coulommiers, 1081. Fontenay-Trésigny. Category 3 "Qp > 1000 tDM and Qa < 1000 tDM": 1002. Bonneuil-en-France, 1007. Asnieres-sur-Oise, 1009. Rosny-sur-Seine, 1010. Corbeil-Essonnes, 1014. Marolles-saint-vrain 2, 1015. Persan, 1016. Grande-Paroisse, 1033. Nemours, 1037. Morigny-Champigny, 1053. Villeparisis, 1061. Gazeran-La-Gueville, 1062. Limay, 1092. L'isle-Adam, 1097. Verneuil, 1109. Evry-Centre-CAECE.

(2). Collecting zones of the important wastewater plants

The collecting zones were visualized in Fig. 7-1 for the plants in the first three categories, which represented the origin area of 95% of the total sludge production and 92% of the total amount entering land application of Ile-de-France (the total amounts of the 462 plants selected in this study, see section 2.1 of Chapter 6). The 4-year sewage sludge production of the 462 plants was 697 895 tDM, and the total amount into land application was 275 027 tDM.

A. Plants having important amount of sewage sludge to land application

Plants having important amount of sewage sludge to land application include Category 1 (Qp > 1000 tDM and Qa > 1000 tDM) and Category 2 (Qp < 1000 tDM and Qa > 1000 tDM).

The collecting zone of SIAAP is the biggest and most important origin area of sewage sludge for land application, considering the distribution of population density in Ile-de-France. Its adjacent sanitation areas had also important amounts of sewage sludge valued in land application. They are the collecting zones of (**i**) Auvers-sur-Oise (1025), Cergy-Pontoise-Neuville-sur-Oise (1003) and Les Mureaux (1005) to the north-west, (**ii**) the Villiers-Saint-Frédéric (1011), Elancourt (1026), Villepreux (1038), Maurepas (1039), Carré-de-Réunion (1013) and Le-Val-des-Eglantiers (1201) to the west, and (**iii**) Lagny-Sur-Marne-St-Thibault-des-Vignes (1004) and Presles-en-Brie (1048) to the east.

Other important sanitation areas relying on land application scatter in the department of Seine-et-Marne, the biggest rural department of Ile-de-France. They are the collecting zones of (**i**) Dammarie-Les-Lys and Boissettes (1008), Saint-Fargeau-Ponthierry (1054), Fontainebleau-Avon (1049) and Veneux-Les-Sablons (1032) in the south, (**ii**) Meaux (1012) and Sept-Sorts (1017) in the north-east and (**iii**) Provins (1029) in the remote south-east. The collecting zones of the two pants in category 2, namely, the Coulommiers (1069) and Fontenay-Trésigny (1081) are located in the center of Seine-et-Marne.

B. Plants with important sewage sludge production and relying on alternative strategies

Category 3 (Qp > 1000 tDM but Qa < 1000 tDM) includes the plants that had important production of sewage sludge but preferred other outlets than land application. The collecting zones of these plants are mainly located in the western half of Ile-de-France.

To the north of the limit of SIAAP, there are Bonneuil-en-France (1002), Asnieres-sur-Oise (1007), Persan (1015) and L'isle-Adam (1092), and Villeparisis (1053) to the north-west. To the south, there are Evry-Centre-CAECE (1109), Corbeil-Essonnes (1010), and Marolles-saint-vrain 2 (1014). To the west there is the Verneuil (1097). The others scatter in the west of Ile-de-France: Rosny-sur-Seine (1009), Limay (1062), Gazeran-La-Gueville (1061), and Morigny-Champigny (1037). Only two are in the south of Seine-et-Marne: Grande-Paroisse (1016), and Nemours (1033).

Among them, Villeparisis and Evry-Centre relied primarily on landfilling as the outlet of sludge. Rosgny-sur-Seine and Marolle-saint-Vrain relied primarily on incineration. Asnière-sur-Oise, Persan, L'isle-Adam, Limay, Corbeil-Essonnes, Grande-Paroisse, and Nemours relied primarily on composting. Bonneuil-en-France and Gazeran-La-Gueville also did composting as primary choice but the compost remained in the status of “waste”. The outlets of their sludge are unknown without complementary data, because these composts can either be output to land application, incineration or other destinations. Morigny-Champigny sent most of their sludge to other treatment plants.

Thus, agricultural land application is always an important strategy for the Parisian agglomeration to handle with their sewage sludge. The peripheral plants that have an important production of sewage sludge may prefer other outlets. They are mainly located in the western half of Ile-de-France, while those in the Seine-et-Marne still favor land application. As for those prefer other outlets than land application, the plants at the fringe of the Parisian agglomeration principally rely on incineration or landfilling and the ones scattering in the rural suburbs turn to composting and convert the sewage sludge into “products”.

1.2. Municipal potential regarding agricultural lands suitable for sewage sludge application

1.2.1. General structure of agricultural lands in Ile-de-France

Agricultural lands in Ile-de-France are dominated by the system of “Grande Culture”. Farmers of “Grande Culture” are the most interested by land application of sewage sludge because of the separation of crops and livestock.

According to Fig. 7-2, wheat is the most important crop type, followed by barley, rape, corn, protein crops and industrial crops. Fallow lands are also visible. These are basic components of the system of “Grande Culture” (Chapter 2 has detailed analysis of the agricultural systems in Ile-de-France). The other land types, such as permanent meadows, vegetable and flowers, fruits, wines, nuts, arboriculture have very limited areas. Sunflowers, fibre plants, seeds, grain legumes, forage and temporal meadows also appear in the system of “Grande Culture”, but the area of these crop types are very limited. The area of each crop type is relatively stable between the years, except for the corns, barleys and rapes in a rising trend and fallow lands in a decreasing trend.

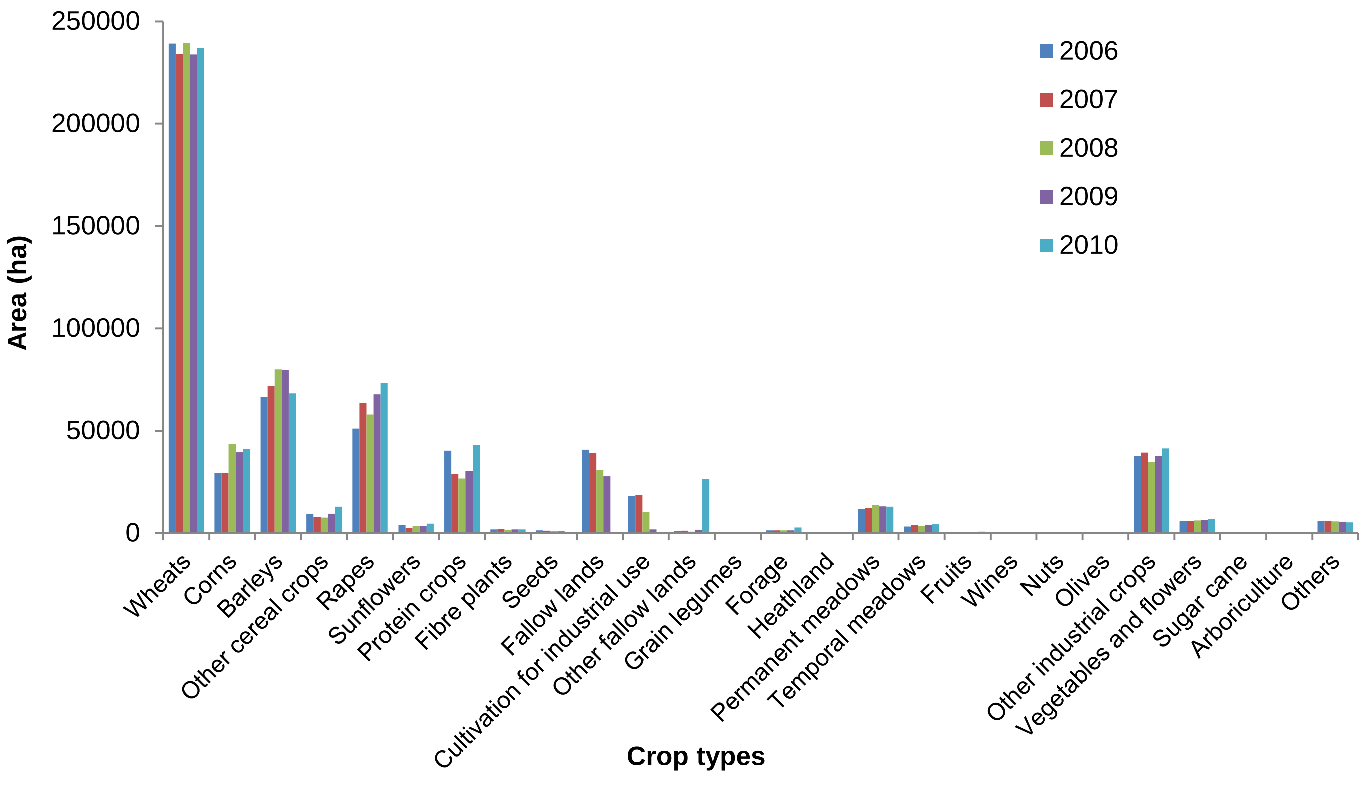


Fig. 7- 2. Area of crops and evolution along the time

The study used the “number of crop types per hectare” (Nc/ha) as a first step to select land parcels of “Grande Culture”. Fig. 7-3 shows the curves representing the sub-total areas of land parcels with different value of Nc/ha from 2006 to 2010. Fluctuations between the years mainly happened in the interval 0.04-0.08 and the interval 0.12-0.25 of Nc/ha. The fluctuations are results of the changes within the system of Grande Culture (e.g. crop succession or land rearrangement). The sub-total areas for the interval 0.04-0.08 increased from 2006 to 2010, while the sub-total areas for the interval 0.12-0.25 decreased correspondingly. This suggests many possible changes, among which, two possibilities are (i) some land parcels of 4-8 hectare were grouped into 12-25 hectare from 2006 to 2010 (ii) some three-field systems were replaced by cultivations of only one crop type. Anyway, the results reveal that Nc/ha = 0.25 (i.e. 0.255) can be used as a threshold to select the lands of Grande Culture because above the threshold the sub-total area did not change between the years.

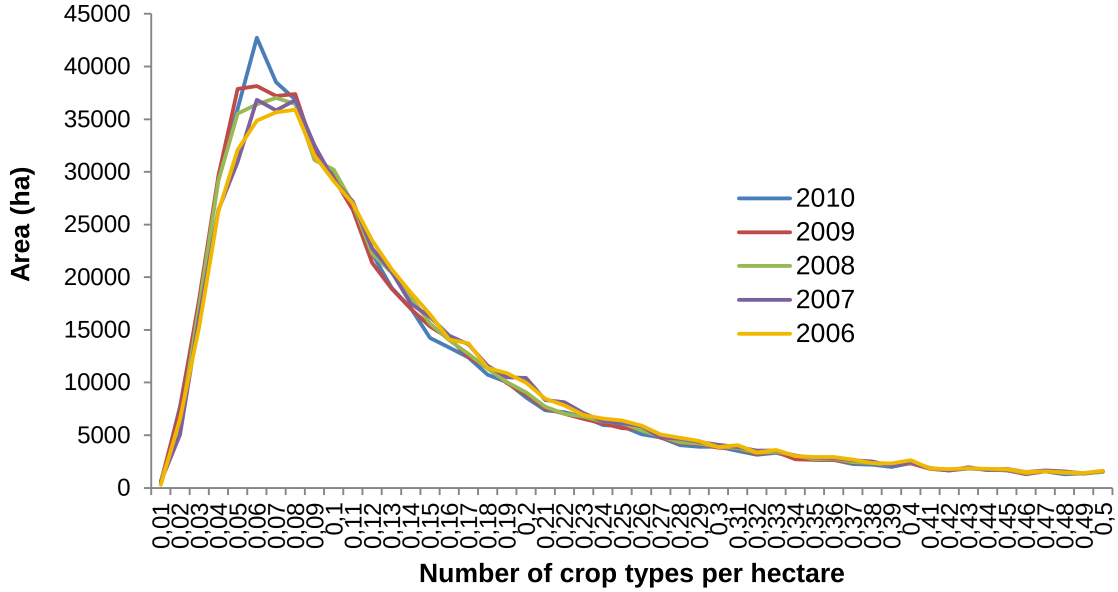


Fig. 7- 3. Sub-total areas of land parcels with different value on “number of crop types per hectare” (the value of the horizontal axis: 0.01 means the interval 0.005-0.015; 0.02 means the interval 0.015-0.025)

1.2.2. Area of agricultural lands suitable for sewage sludge application at the municipal level

The area of suitable agricultural lands were estimated based upon the distribution of the lands in Grande Culture and the isolation distances to habitation, water area, rivers and area for potable water production imposed by the regulation. The analysis identified 427 287 ha of agricultural lands potentially suitable for land application of sewage sludge, representing 74.9% of the area declared in RPG in 2010.

However, I remind the readers that sewage sludge application will also consider other factors. For example, according to the Decree of 1997 and the Order of 1998, it is forbidden to apply sewage sludge in the soil with PH < 5. The sludge should be limed when the soil PH < 6 and the acceptable thresholds for the content of metal elements in the sludge are also lower than in normal condition. These limits are for the concern that metal elements have higher mobility in the soil with a low PH. The regulation has also fixed the periods in a year when the land application is allowed. The time periods vary with the types of organic waste and the crop types that receive the waste. Then, the crop succession on the lands will also influence because the sludge application should match the growing season and needs of plants with the time periods allowed by the regulation.

Thus, it is impossible to get a credible regional map about the potential to receive sewage sludge application in terms of quantity. But the distribution of suitable agricultural lands can indicate the regional pattern of hotpots regarding sewage sludge application. The soil was not particularly considered here because the systems of Grande Culture in Ile-de-France normally occupy the best agricultural lands on the plateaus covered by a deep silt loam soil (see Chapter 2).

Table 7-3 presents the result of statistics on municipalities regarding the area available for sewage sludge application. A total of 1046 municipalities are concerned. Most of them have 100-300 ha suitable area within the municipal limits, representing 30.6% of the municipalities, but the sub-total of the suitable area only represents14.4% of the total area. The grade of 500-1000 ha concerns 21.3% of the municipalities, but represents 36% of the total area, the highest among the different grades. 80 municipalities have 1000-2631 ha suitable area within their municipal limits, accounting for 26.9% of the total area. 195 municipalities have less than 100 ha suitable area, accounting for only 2% of the total area.

Table 7- 3 Statistics on municipalities regarding area available for sewage sludge application

Area of agricultural lands available in a municipality (ha)	Number of municipalities	%	Sub-total area of agricultural lands available (ha)	%
0-100	195	18.6	8 451	2.0
100-300	320	30.6	61 478	14.4
300-500	228	21.8	88 635	20.7
500-1000	223	21.3	153 697	36.0
1000-2631	80	7.6	115 026	26.9
Total	1046	100	427 287	100

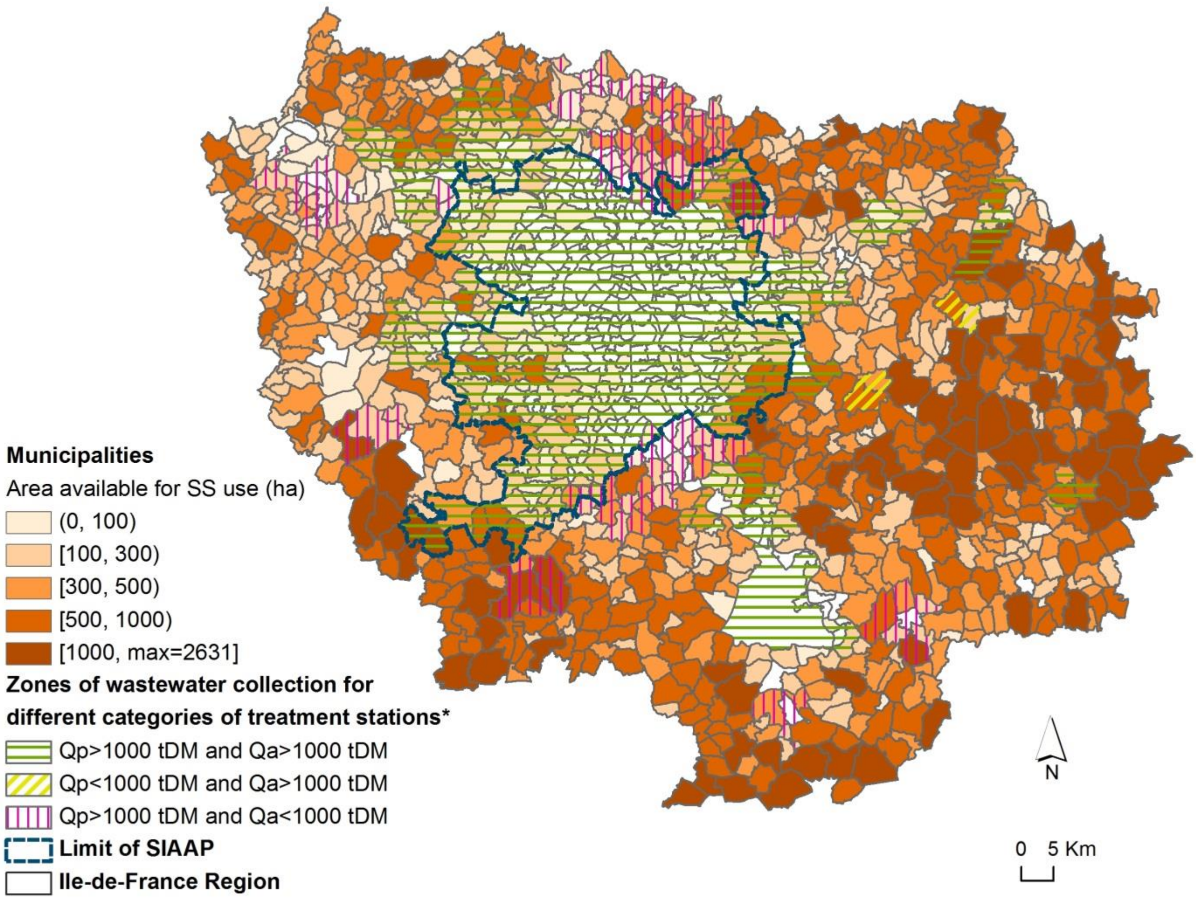


Fig. 7- 4. Agricultural lands available for sewage sludge application compared with the principal origin areas of sewage sludge. SS means sewage sludge. The collecting zones were explained in section 3.1.1.

As for spatial pattern, Fig. 7-4 compares the distribution of available agricultural lands at municipal level with the principal origin areas of sewage sludge. The municipalities with the largest suitable area (> 1000 ha) are many located in the plateau of Beauce in the south-west, Gatinais in the south, and the plateau of Brie in the east. The plateau of Vexin in the north-west and the Butte-de-Dammartin in the north-east also have important number of municipalities that have 500-1000 ha of suitable area for sewage application. In other four zones, many municipliaties have 300-500 ha of suitable lands: the Plaine de Versaille in the west, Hurepoix between the plateau of Beauce and the Parisian agglomeration, the vast valley of Bassée in the south-east under the plateau of Brie, and the Vieille France to the north of the Parisian agglomeration.

The overall pattern is the mismatch between the principal origin areas of sewage sludge and the distribution of agricultural lands suitable for sewage sludge application. The scope of SIAAP only covers several municipalities at its fringe that have 500 ~ 1000 ha suitable agricultural lands. Inside its scope only the Plateau de Saclay have some area potentially suitable for sewage sludge application.

In the north-west, the sanitation zone of the plant Cergy-Pontoise-Neuville-sur-Oise and the plant Les Mureaux cover several municipalities with important suitable agricultural lands. They are adjacent to the agricultural zone of Vexin, so possibly their sludge was applied in Vexin. Similarly, the plants in the Ville-Nouvelle Saint-Quentin-en-Yvelines need to turn to the west and apply their sludge in the Plaine de Versaille and even further into Drouais. The plant Gazeran-La-Gueville and the plant Morigny-Champigny are close to the plateau of Beauce, but do not output the sludge towards land application, possibly because of technological problems: Gazeran-La-Gueville did composting but the compost remained as “waste”; and Morigny-Champigny send majority of sludge to other plants.

In the eastern half of Ile-de-France, the department of Seine-et-Marne have large area of agricultural lands suitable for sewage sludge application. The plants Presles-en-Brie, Setp-sorts, Provins, Coulommiers, and Fontenay-Trésigny all have important suitable area within their wastewater collecting zones. The two plants near the agricultural area Gâtinais, namely, Grande-Paroisse and Nemours choose to convert their sludge into products by composting.

1.3. Spatial flows of sewage sludge through land application in Seine-et-Marne

This section examines the supply-demand relationship of sewage sludge based upon the real spatial flows from wastewater plants to agricultural lands in Seine-et-Marne in 2009. In total, 84 685 t (gross weight) sewage sludge were applied in 5573 ha agricultural lands, dispersing in 136 municipalities. According to the analysis in section 1.2.2, Seine-et-Marne has 255 940 ha agricultural lands suitable for sewage sludge application, representing 60% of the total suitable area of Ile-de-France. So the area of sewage sludge application in 2009 accounted for only 2.2% of the total suitable area of Seine-et-Marne.

1.3.1. An overall picture of the spatial flows in Seine-et-Marne

Fig. 7-5 shows the spatial distribution of the 138 municipalities that received sewage sludge in 2009 and distinguishes them into 4 categories according to the origins of sewage sludge.

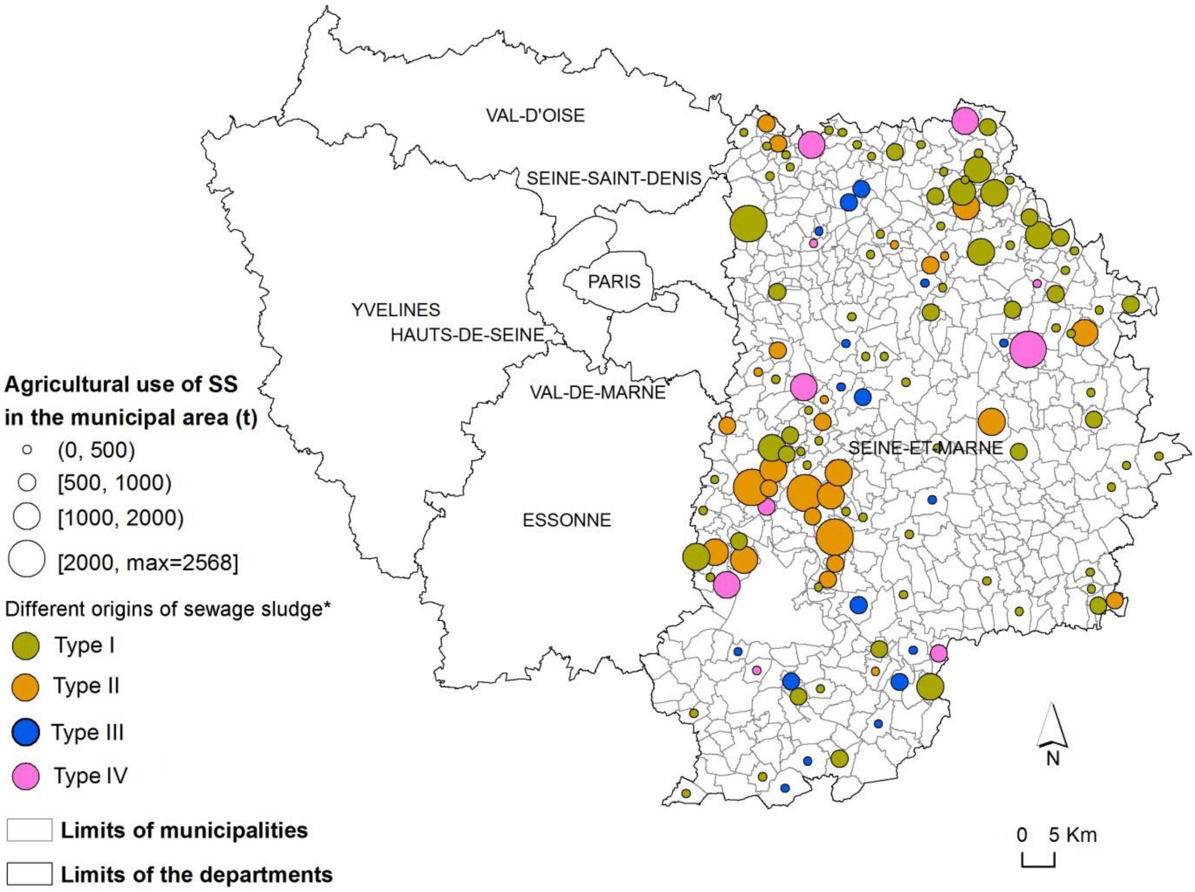


Fig. 7- 5. Reception of sewage sludge for land application in 2009 in Seine-et-Marne. SS: sewage sludge. Categories according to origins of sewage sludge: Type I. mono-external origin, Type II. multiple-external origins, Type III. self-produced, Type IV. external origins and self-production.

Type I signifies that the sewage sludge came from an external wastewater plant, i.e. outside the sanitation zone that the municipality joined. 82 municipalities are in this category, and represent 46.1% of the total amount of sewage sludge applied in Sein-et-Marne in 2009. They used on average 14.7 t GW (gross weight) sludge per hectare.

Type II signifies that the sewage sludge came from two and more external plants. 27 municipalities are in this category, and represented 33.8% of the total amount of sludge. They used 15 t GW sludge per hectare on average. Sewage sludge cannot be mixed according to the regulation. Here the sewage sludge from different plants was applied on different land parcels.

Type III signifies that the sludge only came from self-production, i.e. from the plant in charge of the sanitation service of the municipality. 17 municipalities are in this category, and accounted for 8.4% of the total amount of sludge. They used 24.2 t GW sludge per hectare on average.

Type IV signifies that the municipality applied the sewage sludge produced by its own plant and by one or more external plants. 10 municipalities are in this category, and applied 11.6% of the total amount. They used 15 t GW sewage sludge per hectare on average.

Therefore, majority of sludge was applied in a different area from where the wastewater came from. The type III applied more sludge per hectare in terms of gross weight, while the level in other three categories was quite close. The amounts of sludge application were commonly small in the municipalities of Type III. Their plants are also small sized according to Fig.6-1 in Chapter 6. Therefore, it does not necessarily mean that the municipalities in Type III used more sludge per hectare in terms of dry matter weight. The small-sized plants usually output liquid sludge instead of dewatered sludge short of equipment and technology.

The most important amount of sewage sludge application concentrated in a zone to the north of Fontainebleau and close to the Parisian agglomeration. Another zone is located in the north-east of Seine-et-Marne. In the zone to the north of Fontainebleau, the municipalities are mainly of Type II, and received sewage sludge from multiple external plants. In the zone in the north-east, the municipalities are mainly of Type I, and received sewage sludge from only one external plant. Villeparisis in the north-west of Seine-et-Marne applied 2568 t GW sewage sludge from a neighbouring plant Villevaudé, but its own plant relied on landfilling as the only outlet of sludge. The municipalities of Type III are mainly located in the central and southern part of Seine-et-Marne, away from the two zones of hotpots. The municipalities of Type IV are located on the fringe of the two zones of hotpots.

1.3.2. Spatial flows of sewage sludge from particular plants

Fig.7-6-1 and Fig.7-6-2 visualize the spatial flows from particular sewage plants to the municipalities that applied their sludge, and compare the flows with the wastewater collecting zones of the plants identified in section 1.1.2.

Fig.7-6-1 (a) shows the flows from two plants of SIAAP to Seine-et-Marne. The sewage sludge from Seine-Aval was applied in the north of Seine-et-Marne besides in La Chapelle-Gauthier. Sewage sludge from Seine-Amont was applied in the south-east fringe of Seine-et-Marne. However, these areas were only a small part of the perimeter authorized for the sludge application of SIAAP. For example, as Fig. 7-7 shows, the sludge of Sein-Aval can be not only applied in Yvelines, Val d'Oise and Seine-et-Marne, but also in 10 other departments out of Ile-de-France. Fig.7-6-1 (b) presents the spatial flows from three plants to agricultural lands. The plants Boissettes and Dammarie-Les-Lys belong to a same sanitation syndicate. The zones for sludge evacuation of the two plants partly overlaid and both were composed by municipalities surrounding the plants. The plant Lagny-sur-Marne-Saint-Thibault-des-Vignes output its sludge toward the municipalities scattering in the west and only one (Bussy-Saint-Martin) was located in its wastewater collecting zone.

Fig.7-6-2 (a) presents the flows from 4 plants. The outlet zones of the plants Sept-Sorts, Presles-en-Brie and Provins were more or less not far from the plants. The plant Meaux was different and output their sludge to the municipalities in the north-east fringe of Seine-et-Marne, besides to Boutigny which is adjacent to Meaux. The municipality Presles-en-Brie itself applied a part of sludge from its own plant. Fig.7-6-2 (b) presents the flows from another four plants. Their amounts of land application were less important than the other 8 plants. Fontenay-Trésigny output its sludge only to the lands within its municipal limits, and the plant Fontainbleau-Avon output it sludge to a neighbouring municipality Héricy. The plants Saint-Fargeau-Ponthierry and Verneux-les-Sablons output their sludge to a neighbouring municipality and two farther ones, respectively.

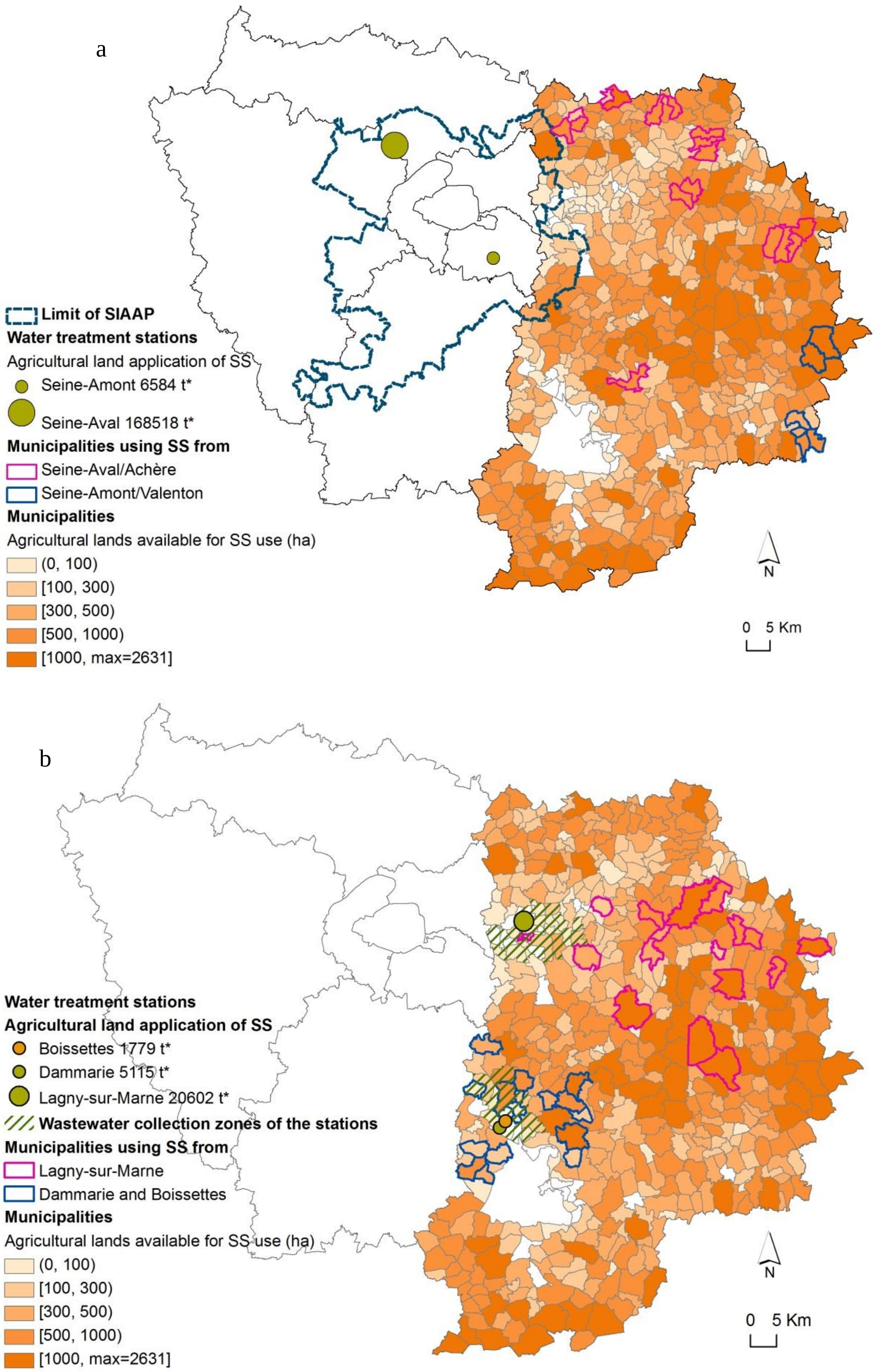
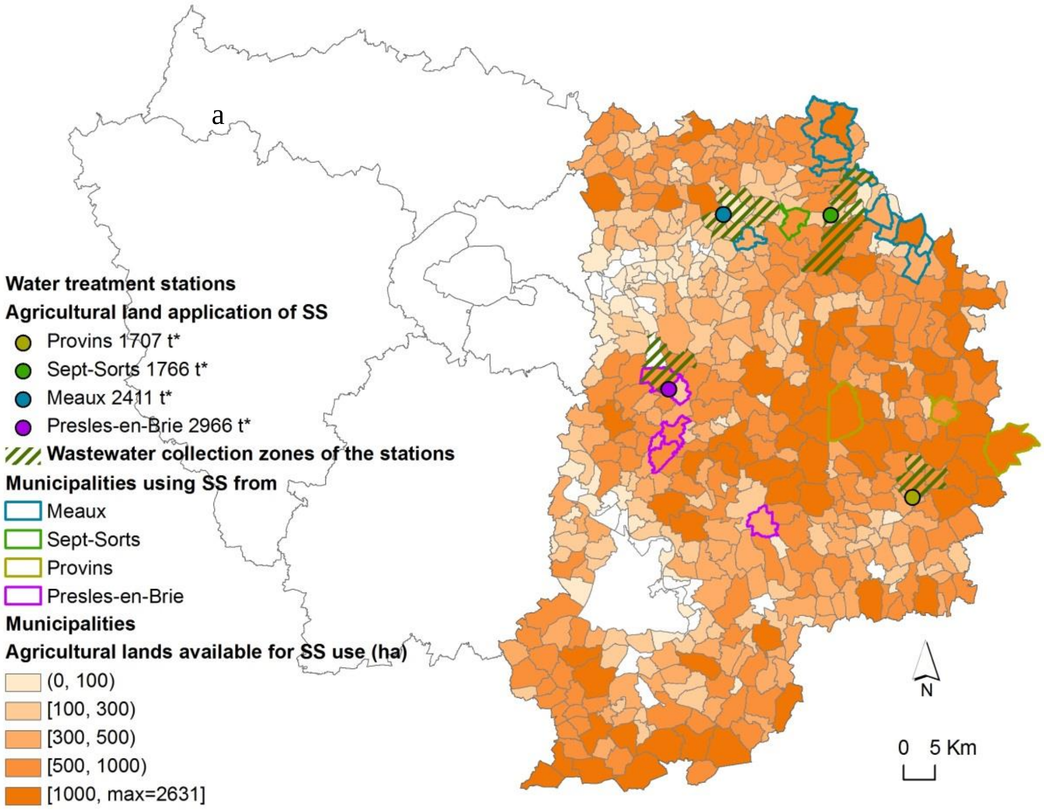


Fig. 7- 6-1. Spatial flows of sewage sludge of particular wastewater treatment plants



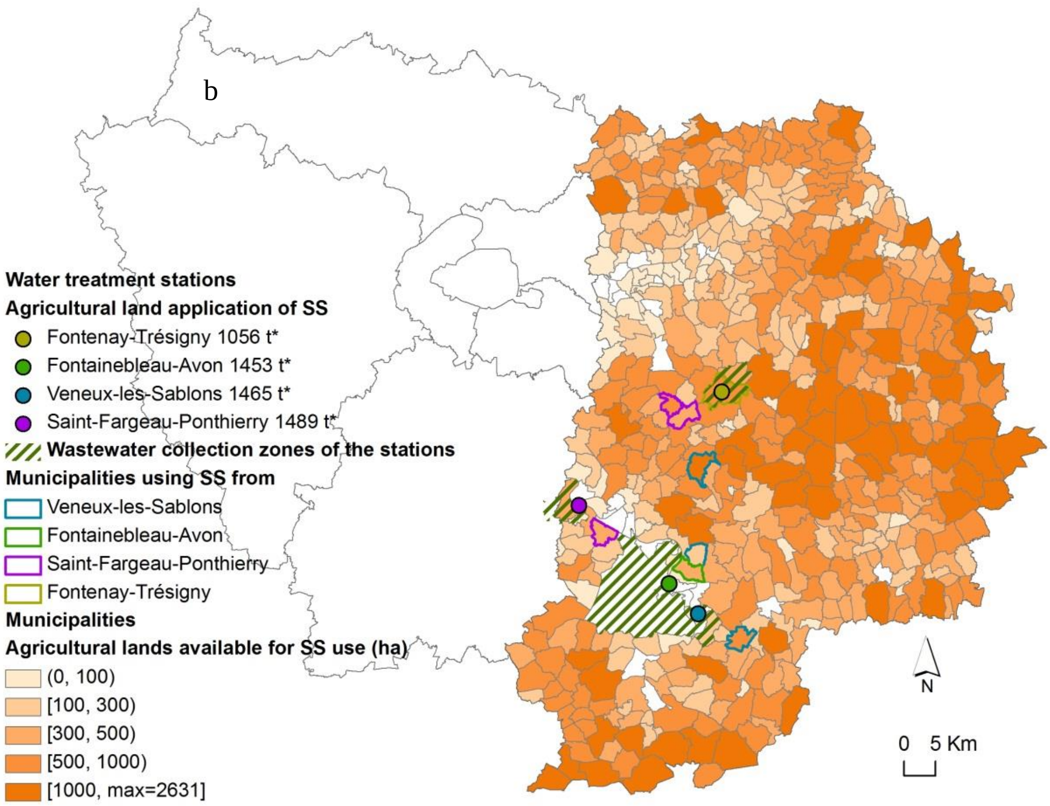


Fig.7-6-2. Spatial flows of sewage sludge from particular wastewater treatment plants

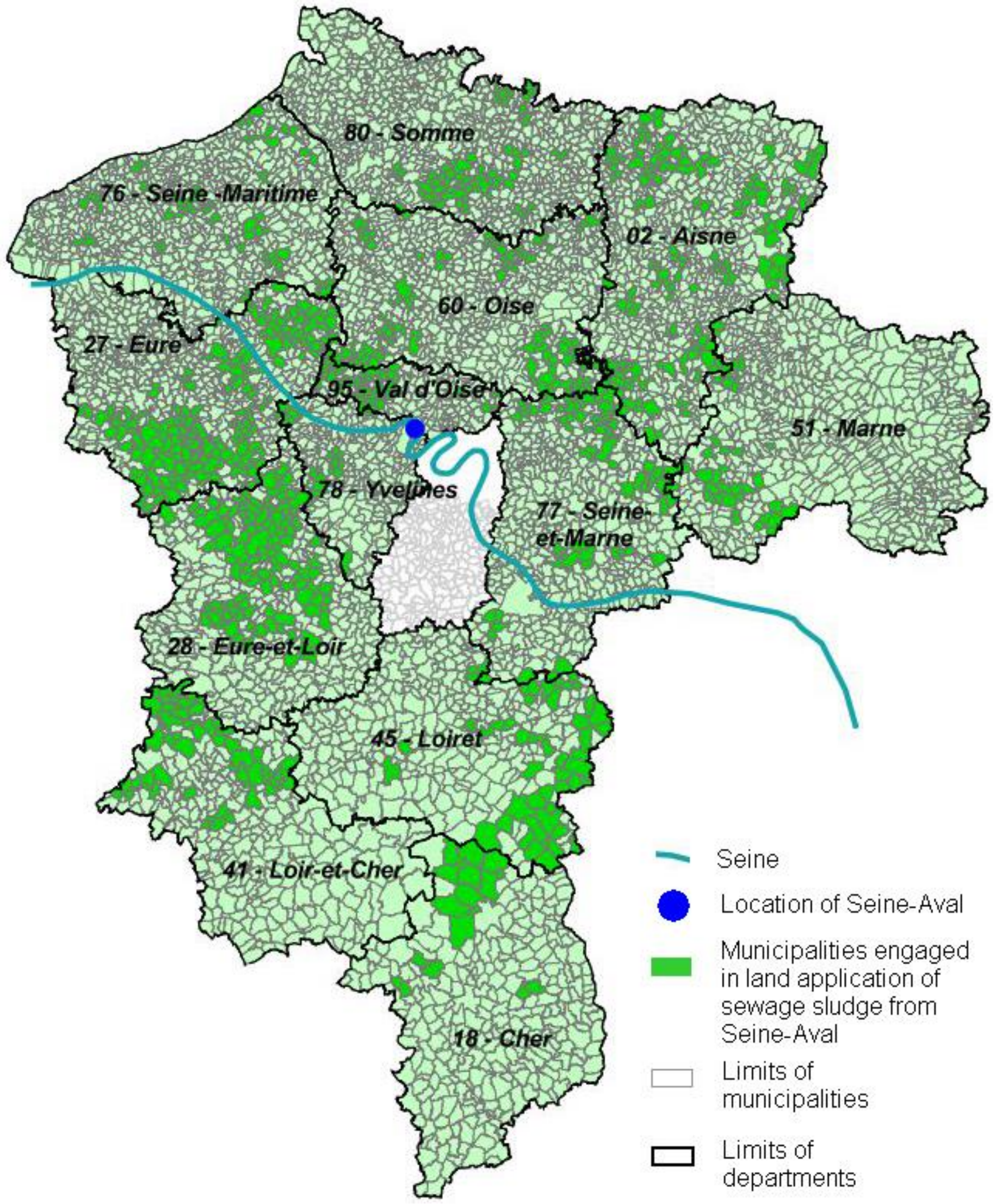


Fig. 7- 7. Perimeter of authorized area for land application of sewage sludge of Seine-Aval. Source: Website of Seine-Aval.

Therefore, for these plants importantly relying on agricultural land application, there are two kinds of spatial flows of sewage sludge: (i) towards vast rural areas in the east of Seine-et-Marne, (ii) to the municipalities surrounding the plants. Bigger plants tend to send their sludge to farther areas. For smaller plants, the geographical proximity is more important. The outlet zones of big plants are not coincident and are basically offset from each other. For a same plant, the collecting zone of wastewater and outlet zone of sludge do not match and only a small part is applied within the origin zones of wastewater. SIAAP, as the biggest sanitation organisation in Ile-de-France, outputs most of their sludge to the remote rural areas outside Ile-de-France. Thus, other big plants after Seine-Aval of SIAAP are the most concerned by the question of waste recycling service between peri-urban agriculture and urban population.

1.4. Estimation of the regional pattern of crop succession

Crop succession is an important factor influencing on the periods and amount of sewage sludge application. Estimation on the regional pattern of crop succession allows going further in understanding the regional pattern of potentials to receive sewage sludge for land application.

1.4.1. Preferences to crop types and periods for sewage sludge application

First, it was possible to investigate the preferences to different crop types for sewage sludge application based upon the parcel-level records in Seine-et-Marne in 2009 (the same database used in section 1.3). Table 7-4 presents the results of statistics on the quantity and area of sewage sludge application according to crop types and the periods. Rape was the most important crop type regarding reception of sewage sludge, accounting for 33.8% of the total area of sewage application in Seine-et-Marne, followed by wheat (20.4%), Sugar beets (22.1%) and Corn (14.3%). The sum of the rest crop types accounted for less than 10%. This difference among crop types should not be a result of limitations regarding available area, because the area of sewage sludge application in 2009 accounted for only 2.2% of the total suitable area of Seine-et-Marne. The study of Dhaouadi (2014) in the Plaine de Versailles also revealed that farmers normally applied sewage sludge on rape, and not on wheat for worrying about negative impacts on the quality of their wheats. Rape can absorb a significant portion of the nitrogen from the soil in the autumn after the sludge application in the summer, and thus reduces the amount of nitrate leaching during the winter.

Table 7- 4 Area of sewage sludge application according to crop types and periods of application in Seine-et-Marne in 2009

Crop types	Quantity of sewage sludge used		Area of land application		Area according to the date of land application (ha)									
					Feb	Apr	Jul		Aug		Sep		Oct	
	t	%	ha	%	16-28	1-15	1-15	16-31	1-15	16-31	1-15	16-30	1-15	16-31
Oat	171	0.2	9.5	0.2						9.5				
Sugar beet	16245	19.2	1227.0	22.1					497.7	505.9	143.5	76.5		3.4
Wheat	19456	23.0	1134.8	20.4		10.5	70.3	39.6	383.2	321.8	101.4	168.7	9.2	30.1
Rape	30183	35.8	1878.5	33.8		40.9		74.5	1089.3	565.5	12.2	35.2	60.9	
Flower	102	0.1	14.4	0.3					14.4					
Corn	10814	12.8	795.3	14.3	8	19		20	207.9	138.4	254.3	69	56.1	22.6
Corn-silage	328	0.4	34.4	0.6					24.4				5	5
Winter barley	2690	3.2	175.9	3.2					18.1	91.2	5.2	61.4		
Spring barley	2062	2.4	137.1	2.5					83.7	22.9	10.5	20		
Potato	887	1.1	50.0	0.9					35.8	14.2				
Meadow	77	0.1	2.6	0.0					2.6					
Sunflower	1156	1.4	71.7	1.3					30.8	7.5	26	7.4		
Triticale	245	0.3	27.2	0.5					27.2					
Sum	**84416**	**100**	**5558.4**	**100**	**8**	**70.4**	**70.3**	**134.1**	**2415.1**	**1676.9**	**553.1**	**438.2**	**131.2**	**61.1**

There are two periods for sludge application in a year. The first period is in the spring. The earliest application in 2009 in Seine-et-Marne happened in late February on corn. But the area for this period counted only 8 ha, and more applications were carried out in the first half of April on corn, rape and wheat. The second period lasts from early July to late October. Sewage sludge is applied before seeding. Majority of application happened in August in 2009, in a total area of 4092 ha. For comparison, the area of application in July, September and October was 204.4 ha, 991.3 ha, and 192.3

ha, respectively. For wheat and sugar beet, sludge application primarily happened in the whole month of August. And for rape, the first half of August was the most important period, followed by the second half of August. The primary period for corn was the first half of September, and the whole month of August is also important.

1.4.2. Estimation of crop succession pattern in Ile-de-France

Then, the crop succession pattern in Ile-de-France was estimated based upon the five-successive-year data of RPG from 2006 to 2010. The analysis was only carried out on land parcels with only one crop type every year in the period. Thus the area analyzed is 162 224 ha, accounting for 27.8% of the total area of RPG in 2010. The 28 crop types of RPG were integrated into 9 categories and coded as following (see section 2.4 of Chapter 6 for detailed process of regrouping): 1. wheats, 2. corns, 3. barleys, 4. other cereal crops, 5. rapes, 6. protein crops, 7. fallow lands, 8. other industrial crops, 9. other various crop types. The crop succession pattern is interpreted progressively through three steps:

(1). Number of crop types in the crop succession trajectories

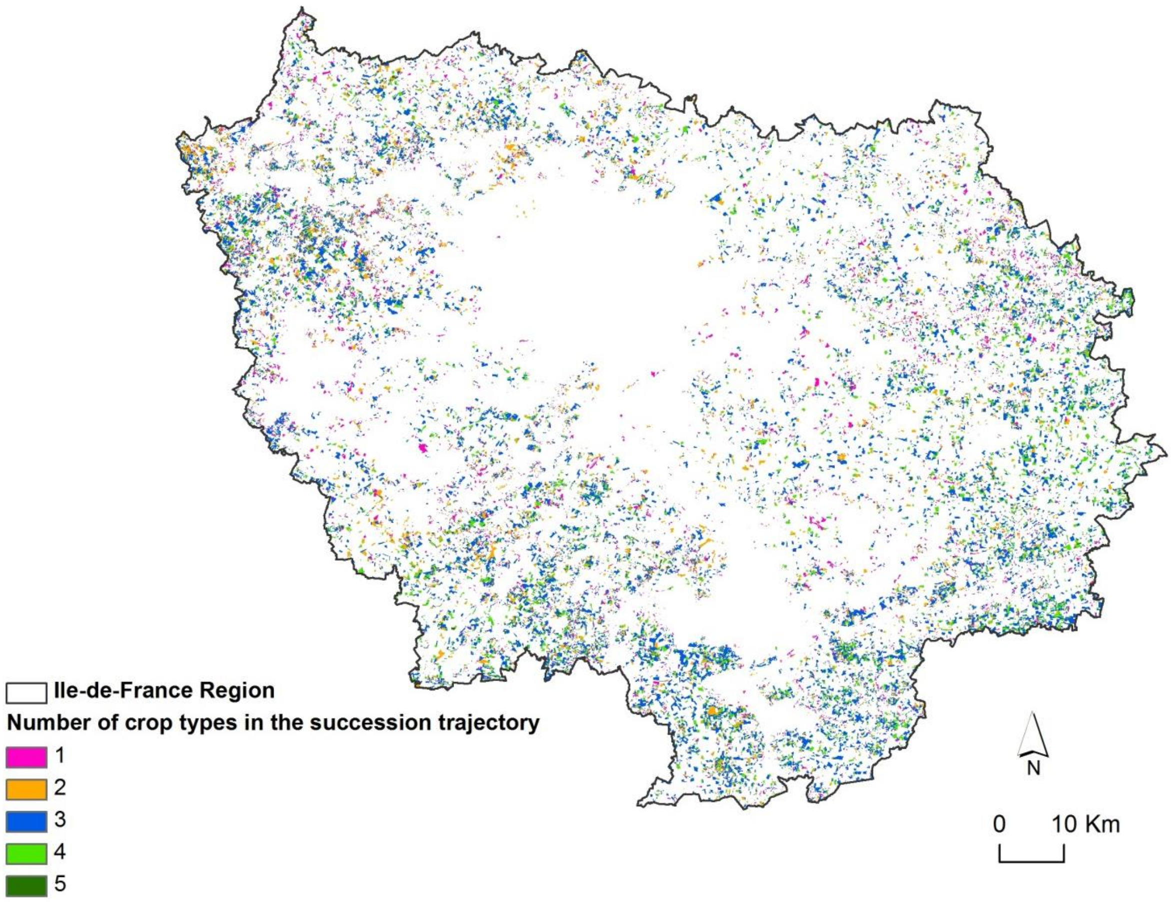


Fig. 7- 8. Number of crop types in the succession trajectories from 2006 to 2010

Fig. 7-8 presents the spatial pattern regarding number of crop types in the succession trajectory of a land parcel. In fact, monoculture was very rare, representing only 12.5% of the lands analyzed. Inside the lands of monoculture, 50% were fallow lands, 40% were the various crop types outside the main categories, including especially the permanent meadows, and others like fruits, vegetables, seeds, and nuts, and 6% were monoculture of wheat.

28 227 ha lands had 2 crop types in the succession trajectory, accounting for 17.4% of the lands analyzed. 81 503 ha lands had 3 crop types, representing 50.2%. 31 155 ha had 4 crop types, representing 19.2%. And 1008 ha had 5 crop types, representing 0.6%. It's hard to tell from Fig. 7-8 if certain zones were dominated by trajectories of 2 crop types or 3 crop types, but it's quite clear that the monoculture was not common in the vast agricultural zone.

(2). Combinations of crop types in the trajectories

Table 7-5 shows the principal combinations of crop types in the trajectory of a land parcel. The order and recurring times of crop types were not considered. 27 different combinations had a sub-total area > 1000 ha, and the first 3 had over 10 000 ha.

Table 7- 5 The principal combinations of crop types in succession trajectory (sub-total area >1000 ha)

Succession types	Area(ha)	Per.in the total area analyzed (%)	Rank
Group (1, 3, 5)	28827	17.8	1
Group (1, 5)	10501	6.5	2
Group (7)	10208	6.3	3
Group (1, 3, 8)	8380	5.2	4
Group (9)	8126	5.0	5
Group (1, 2, 5)	6726	4.1	6
Group (1, 3, 5, 6)	6175	3.8	7
Group (1, 5, 6)	5834	3.6	8
Group (1, 2)	5253	3.2	9
Group (1, 2, 6)	5251	3.2	10
Group (1, 3, 5, 8)	4894	3.0	11
Group (1, 3, 6)	4665	2.9	12
Group (1, 5, 8)	4402	2.7	13
Group (1, 2, 3)	4351	2.7	14
Group (1, 8)	4045	2.5	15
Group (1, 6, 8)	3363	2.1	16
Group (1, 2, 3, 5)	3186	2.0	17
Group (1, 3, 6, 8)	2746	1.7	18
Group (1, 2, 3, 6)	2282	1.4	19
Group (1, 2, 8)	2124	1.3	20
Group (1, 3)	1998	1.2	21
Group (1, 6)	1488	0.9	22
Group (1)	1395	0.9	23
Group (1, 3, 4, 5)	1347	0.8	24
Group (7, 9)	1241	0.8	25
Group (1, 2, 3, 8)	1179	0.7	26
Group (1, 2, 5, 6)	1166	0.7	27
Sum	**141151**	**87.0**	

Codes of crop types: 1. wheats, 2. corns, 3. barleys, 4. other cereal crops, 5. rapes, 6. protein crops, 7. fallow lands, 8. other industrial crops, 9. other various crop types.

The combination (1, 3, 5), i.e. wheat, barley and rape had a sub-total area of 28 827 ha, accounting for a striking 17.8% of the total area analyzed. The combination (1, 5), i.e. wheat and rape, came in second place, with a total-area of 10 501 ha, accounting for 6.5% of the total area. The area of the following combination types decreased slowly. The combination (1, 3, 8), i.e. wheat, barley and industrial crops, accounted for 5.2%. The combination (1, 2, 5), i.e. wheat, corn and rape, accounted for 4.1%. The first 4-crop combination was (1, 3, 5, 6), i.e. wheat, barley, rape and protein crops, representing 3.8%.

Wheat was the most common crop type. The summed-up percentage of all the combinations containing wheat in Table 7-5 was 74.9%, followed by rape (45%) and barley (43.2%), protein crops (20.3%), industrial crops (19.2%) and corn (18.7%). The monoculture of wheat came in 23th place, accounting for 0.9%.

(3). Interpretation of crop succession types

The analysis on crop succession considers the order and recurring times of crop types in the succession trajectory. The interpretation of crop succession types was conducted only for the ten most important combinations listed in Table 7-5 (sub-total area > 5000 ha).

Analysis suggests that the actual crop succession models in Ile-de-France have close relationship with the historical 3-year rotation system from 16th to 19th century as shown in Fig. 7-9.

Because mineral fertilizer was not commonly used as today, farmers adopted the rotation system “fallow + wheat + March crop”. The first year of fallow period was to prepare the lands for wheat production in the second year. The fallow year concerned three labors, “décoinage”, “retaillage” and “rebinage”, which mean to clear the land, input organic fertilizer, and hoe the land. In the third year, the farmers put on a spring crop like barley and oat. The spring crops were called the “March”, they need less nitrogen than wheat. This rotation system helped to best manage fertilization and pest control.

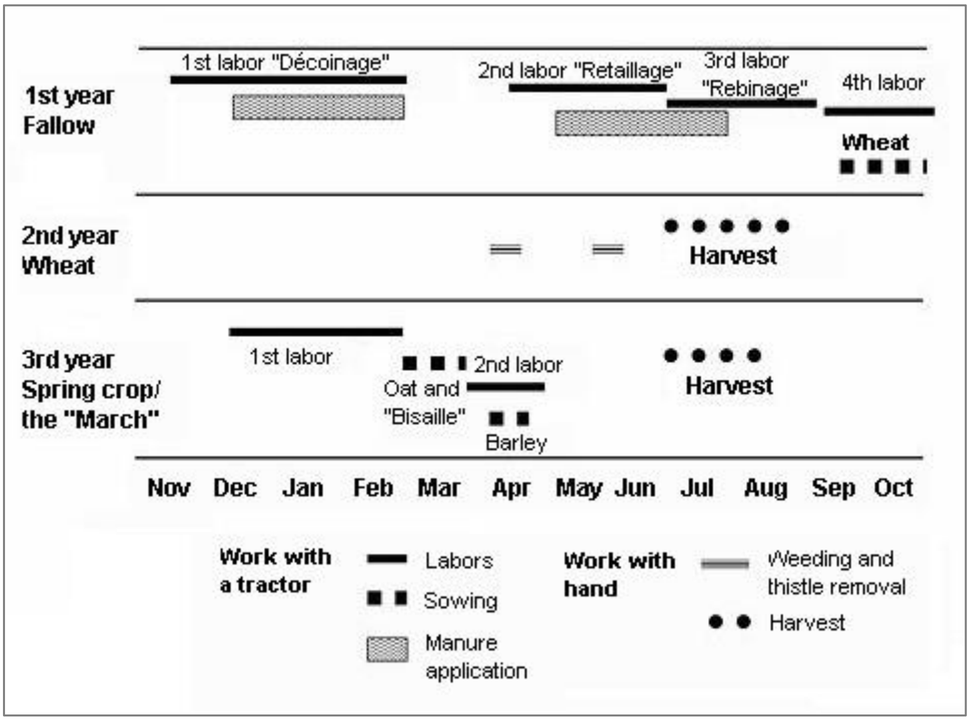


Fig. 7- 9. Working calendar of the three-year-crop-rotation system in Ile-de-France from 16th to 19th century. Translated from Morlon (2013) who adapted from Moriceau (1998)

Model agriculture in Ile-de-France has been freed from the 3-year rotation system because of massive use of mineral fertiliser and pesticides. Even monoculture of wheat is possible. Farmers have commonly deleted the fallow lands. Introduction of new crop types, such as rape, corn and industrial crops has also largely varied the crop succession systems. But the basic idea of the historical 3-year model is always carried on. Overall, the crop succession model can be concluded as “Head + Wheat (+March)”, and the March crop is not necessary. The head crops include corn, rape, protain crops and industrial crops. The March include barleys and other cereal crops.

Table 7-6 presents the results of crop succession analysis. The crop succession type can be interpreted as a basic succession model and its alternative forms.

Table 7- 6 Principal crop succession types

Combination types	Basic succession model	Alternatives	Five most important trajectories during 2006-2010		
			Code	ha	Per. in the group (%)
Group (1, 3, 5)	5-1-3 Rape-Wheat-Barley	5-1-1-3, 5-1-3-3, 5-1-1-3-3, 5-1-1-1-3, 5-1-3-3-3, 5-1-5-1-3, 5-5-1-1-3…	13513	4531.2	15.7
			51351	4000.9	13.9
			35135	3042.8	10.6
			13511	2324.3	8.1
			11351	2137.3	7.4
Group (1, 5)	5-1 Rape-Wheat	5-1-1, 5-1-1-1, 5-1-1-1-1, 5-1-5-1-1, 5-5-1-1-1…	11511	2668.5	25.4
			51151	2232.0	21.3
			15115	1984.2	18.9
			15151	757.9	7.2
			11151	721.9	6.9
Group (1, 3, 8)	8-1-3 Industrial crop-Wheat-Barley	8-1-1-3, 8-1-1-1-3, 8-1-3-3, 8-1-3-3-3, 8-1-1-3-3, 8-1-8-1-3, 8-1-3-1-8, 8-3-8-1-3…	13813	1634.8	19.5
			81381	1345.0	16.1
			38138	849.2	10.1
			18138	630.6	7.5
			13811	425.7	5.1
Group (1, 2, 5)	5-1-2-1 Rape-Wheat-Corn-Wheat	5-1-1-2-1, 5-1-2-1-1, 5-1-5-1-2, 2-1-2-1-5, 5-1-1-1-2, 5-1-2-2-1…	15121	1563.6	23.2
			12151	1139.2	18.4
			51215	663.3	11.4
			21512	495.0	9.4
			21151	342.9	6.5
Group (1, 3, 5, 6)	5-1-3-6-1-3 Rape-Wheat-Barley-Protein crop-Wheat-Barley	5-1-6-1-3, 5-1-3-6-1, 5-1-1-3-6, 6-1-1-3-5, 6-1-3-3-5, 5-1-1-6-3, 5-3-6-1-3…	61351	1124.3	18.2
			13516	610.4	10.5
			16135	571.8	10.9
			35136	450.4	8.6
			35161	382.5	7.8
Group (1, 5, 6)	5-1-6-1 Rape-Wheat-Protein crop-Wheat	5-1-1-6-1, 6-1-1-5-1, 5-1-5-1-6, 6-1-6-1-5, 5-1-1-1-6, 5-1-6-5-1…	16151	1113.8	19.1
			15161	1019.2	19.4
			61151	544.0	10.4
			61516	483.8	9.9
			16115	435.6	9.3
Group (1,2)	2-1 Corn-Wheat	2-1-1, 2-1-1-1, 2-1-1-1-1, 2-1-2-1-1, 2-2-1-1-1, 2-1-2-2-1, 2-2-2-1-1…	12121	1395.9	26.6
			21212	945.3	18.0
			11211	888.4	18.2
			21121	482.4	10.3
			12112	371.1	8.4
Group (1, 2, 6)	2-1-6-1 Corn-Wheat-Protein crop-Wheat	2-1-2-1-6, 6-1-6-1-2, 2-1-1-6-1, 6-1-1-2-1, 2-1-1-1-6, 6-1-1-1-2, 2-1-2-6-1…	16121	1167.1	22.2
			12161	895.4	18.3
			61216	540.7	11.6
			21612	489.1	11.1
			21216	262.5	6.0

The combination (1, 3, 5) has the basic succession model as 5-1-3, i.e. Rape-Wheat-Barley. Alternative forms include "Rape-Wheat-Wheat-Barley", or "Rape-Wheat-Barley-Barley", or "Rape-Rape-Wheat-Barley", and others. Farmers are free in having two or three successive years of wheat or barleys. Table 7-6 has also presented the most important trajectories that appeared from 2006 to 2010. These are the evidence for the estimation of crop succession models. Despite of the alternative forms, the 3 year succession form "Rape-Wheat-Barley" are still the most commonly adopted, accounting for 40% of the group (1, 3, 5).

Similarly, we get the basic succession model "5-1 (Rape-Wheat)", "8-1-3 (Industrial crops – Wheat-Barley)", "5-1-2-1 (Rape-Wheat-Corn-Wheat"), "5-1-3-6-1-3 (Rape-Wheat-Barley-Protein crop-Wheat-Barley)", "5-1-6-1 (Rape-Wheat-Protein crop-Wheat)", "2-1 (Corn-Wheat)", and "2-1-6-1 (Corn-Wheat-Protein crop-Wheat)". Despite of the freedom in doing alternative forms, there are always one or two forms in each group that are the most commonly adopted, as the trajectories from 2006 to 2010 proved.

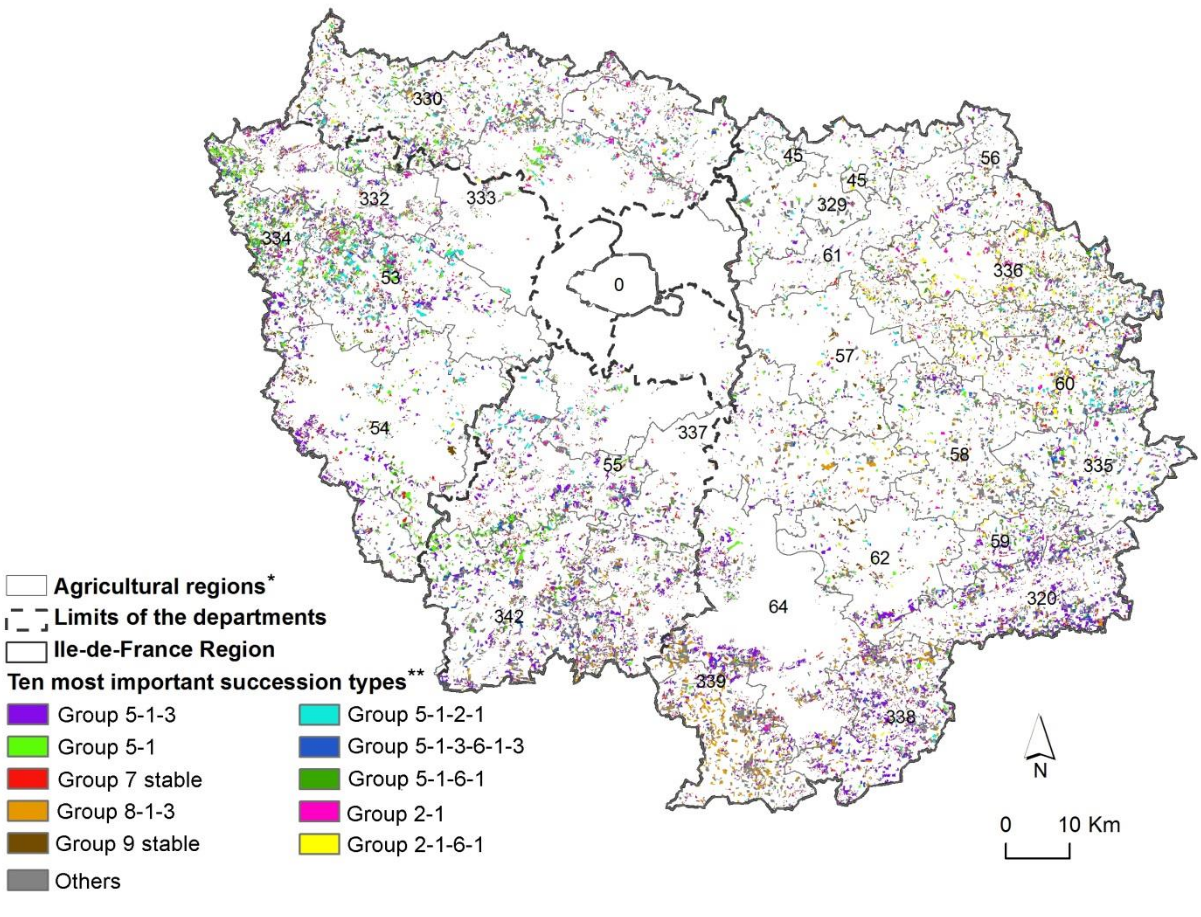


Fig. 7- 10. Distribution of the most important crop succession types. *Names of the Agricultural Regions: 45. Butte de Dammartin; 53. Plaine deVersailles; 54. Yvelines; 55. Hurepoix; 56. Orxois; 57. Brie boisée; 58. Brie Centrale; 59. Montois; 60. Brie Est; 61. Vallées de la Marne et du Morin; 62. Brie humide; 64. Pays de Bière et forêt de Fontainebleau; 320. Bassée; 329. Goële et Multien; 330. Vexin; 332. Vallée de la Seine; 333. Ceinture de Paris; 334. Drouais; 335. Brie Champenoise; 336. Brie laitière; 337. Brie française; 338. Bocage Gâtinais; 339. Gâtinais; 342. Beauce. ** See Table 6 for the signification of succession types. Alternative trajectories in each group are also included.

The spatial pattern of the crop succession types is shown in Fig. 7-10. The succession type “Rape-Wheat-Barley (5-1-3)” are mainly adopted in Hurepoix and plateau of Beauce in the south-west, and Bocage Gâtinais and Valley of Bassée in the south-east. The Group “Rape-Wheat (5-1)” are mainly adopted in Drouais in the west, the Group “Industrial crop-Wheat-Barley (8-1-3)” in Gâtinais in the south-west of the plateau, the Group “Rape-Wheat-Corn-Wheat (5-1-2-1)” in Plaine de Versailles in the west, and the Group “Corn-Wheat-Protein crop-Wheat (2-1-6-1)” in Brie-Laitière in the east.

2. Multiscale influences on the supply-demand relationships of urban waste recycling in peri-urban agriculture

The development of agricultural recycling of urban waste is influenced by multiple factors at different scales. The supply-demand relationships vary depending on the biophysical characteristics of urban waste and agricultural lands, the social perceptions, economic situations and the regional, national and European policies. This section first presents a framework about the multiscale influences on the supply-demand relationships based upon interviews with different actors in two local areas of Ile-de-France (see the section 3 of Chapter 6 for the detailed information of actors). The final parts analyze the different categories of farmers identified in the two local areas according to their practices and perceptions of urban waste use.

2.1. A framework about the multiscale influences on supply-demand relationship

Fig. 7-11 presents a framework concluded from the field studies in the Plaine de Versailles and the Plateau de Sacaly of Ile-de-France. As developed in Chapter 3, the farmers and waste producers have mutual supply-demand relationships in the agricultural recycling of urban wastes. Farmers demand urban waste for the fertilization effects and supply the service for waste eliminating, while the waste producers, such as wastewater plants and the platform of green waste compost, are suppliers of organic fertilizer/amendment and service requester for waste eliminating.

The multiple influences on the supply-demand relationships can be distinguished into three levels: (i) individual scale, i.e. strategy of a farmer or a waste producer, (ii) scale of a local area, i.e. a municipality or an inter-municipal territory, integrating the management of fertilizer and waste eliminating, (iii) regulations at superior scales, i.e. regional, national and European policies.

2.1.1. At individual scale

Multiple factors influence separately on the demand of fertilization and the demand of waste eliminating service. The status of farmers and waste producers in the negotiation changes when the balance between two sides changes.

2.1.1.1. Factors that influence on the demand of urban wastes for fertilization effects

Factors that influence on the demand of urban wastes for fertilization effects include pressures from food markets, complaints from neighbors, internal factors on farmers’ choice and the availability of substitute fertilizers.

(1). Pressures from food markets

Farmers reported worries about problems to sell their food products if they use urban wastes. The Mad Cow crisis in the 1990s has profoundly influenced the food markets in France. From the first announcement on March 20, 1996 in Great Britain to another outbreak in October 2000 in France, the consumers became extremely nervous and emotional in food purchasing following media reports

(Sinaceur et al., 2005). Concerns for food quality extended to other agricultural products. Discovery in late 1990s of the high pollution level in the wastewater spreading zone of Achères has also fueled the mistrust to urban waste. Food industry, in turn, became more precautious. Some food companies and supermarkets require not using urban waste in the contracts with farmers (Barbier and Lupton, 2003). Some farmers spontaneously refuse to use sewage sludge out of precaution (Joncoux, 2013).

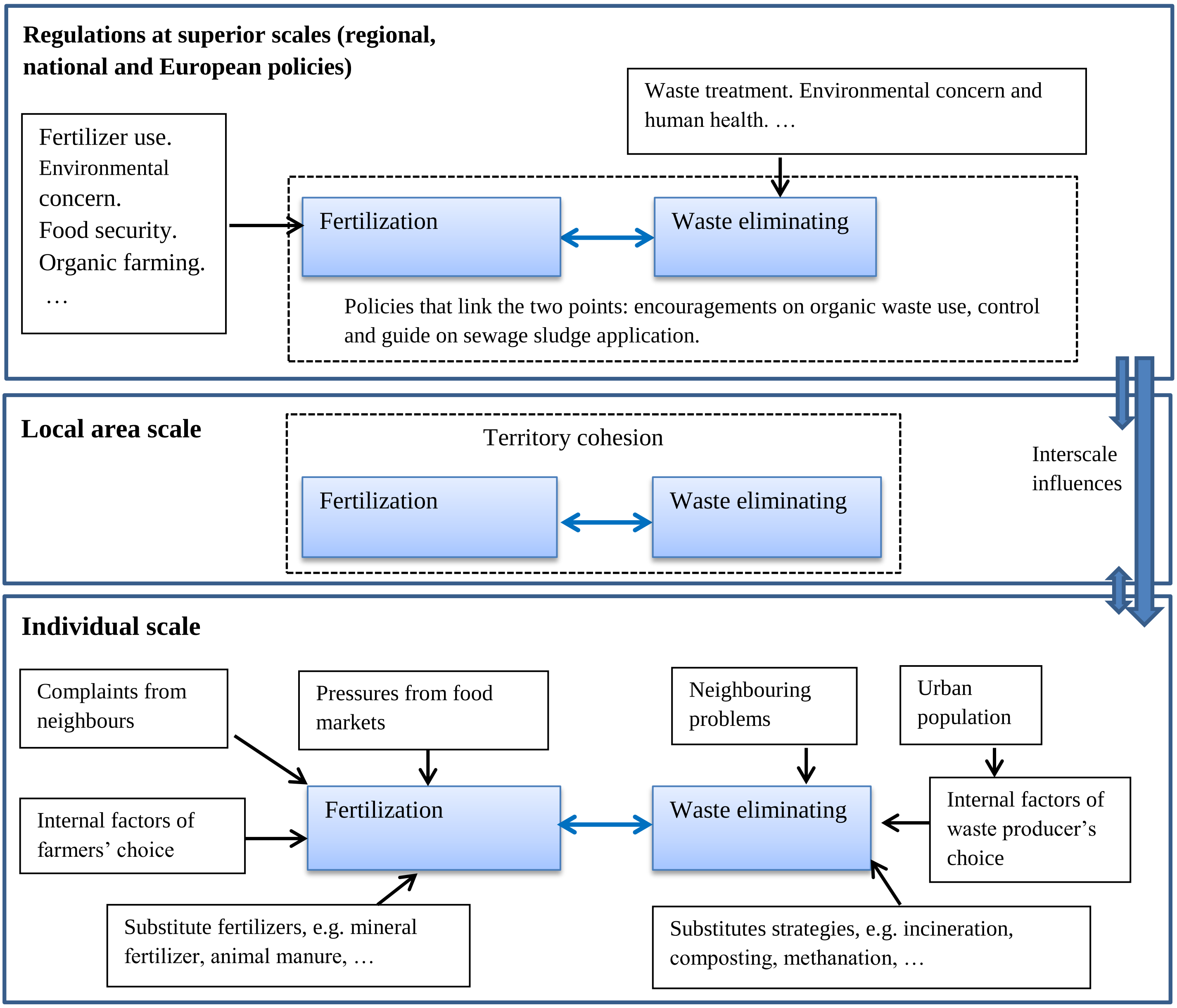


Fig. 7- 11. Multiscale influences on supple-demand relationship of urban waste recycling in peri-urban agriculture

(2). Complaints from neighbors

Neighbors may complain about the odor nuisance of urban waste application or the sanitary and environmental risks. With the rise of urban-rural immigration, the peri-urban population now is mainly composed by people with no rural experience. Their expectation to "rural area" is a natural, quiet and clean space for living. Land application of sewage sludge is not acceptable, especially during the weekends and when there is a marriage ceremony. It is not new; Nicourt and Girault (2003) also talked about this phenomenon. As for the odor nuisance, the dewatered sewage sludge is better than the sludge in liquid or pasty form, and burying the sludge immediately after spreading can alleviate this problem.

(3). Internal factors on farmers' choice

Internal factors of farmer's choice include technic problems and personal reasons. Technic problems first concern the matching between the characteristics of agricultural lands with the quality of urban waste. Characteristics of agricultural lands include the soil property, crop succession and others. As mentioned above, farmers in the Plaine de Versailles applied sewage sludge for rape, but not for wheat, because they have fear of negative impacts on the price of wheat and because wheat needs less nitrogen as rape at the beginning of its cultural cycle. Furthermore, sewage sludge application is prohibited in organic farming.

Technic problems can also influence on farmers' willingness to be engaged in. For example, because of lacking equipment, farmers have to adapt themselves to the timetable of the sludge producer who is in charge of sludge spreading. When the meteorological conditions are not suitable, they have to wait until the weather change.

Personal reason can be farmers' distrust of the urban waste recycling industry. One of the farmers talked about his distrust of waste producers. He thought that the waste producer would mix unqualified sludge with compost in order to sell it. Another one distrusted the regulation because of the rapid change of the latter. He considered urban waste as a risk even if there are control and analysis.

Furthermore, if the farmer is not land property owner, he may be not interested in using organic fertilizer to improve soil structure for long term benefits when he will be soon retired. In another case, the property owner may be opposed to the farmer using urban waste (Joncoux, 2013).

(4). Availability of substitute fertilizers

Availability of the substitutes provides possibilities for farmers to withdraw from urban waste. In turn, advantages of the organic fertilizers that originate from urban waste provide motivations for farmers to replace partly mineral fertilizers.

The sewage sludge is free of cost for farmers, and the green waste compost is also very cheap (varying from 3 to 10 euros/t). They can be interesting substitutes as the price of mineral fertilizer keeps on increasing. Especially, nitrogen is more limiting than phosphate and potash for the system of "Grande Culture" (Agreste, 2012). The study of Dhaouadi (2014) showed that sewage sludge is potentially capable to provide the whole nitrogen needed by plants if applied in the right periods.

The compost of green waste is more interesting for improving the level of organic matter in the soil and ameliorating the soil structure. However, the volume of organic fertilizer is up to ten times of the volume of mineral fertilizer, which results in higher costs for storage, transportation and land application of organic fertilizers. As waste producer is in charge of the land application of sewage sludge, the problem of transportation does not influence on farmers' motivation.

2.1.1.2. Factors that influence on the demand of urban waste eliminating

Similarly, the demand of waste eliminating service can be influenced by neighboring problems, internal factors of urban producers and feasibility of substitute strategies, e.g. incineration, composting and methanation.

(1). Urban population

In Ile-de-France, the volume of waste keeps on increasing because of a rapid growing population (Barles, 2005). Thus there are increasing demands of waste disposal. But the urban population does not participate directly in managing the outlets of their wastes. They get rid of their wastes after paying the water bill or tax for collecting green waste to the municipal service. The sanitation service is usually fulfilled by an intermunicipal syndicate or delegated to a professional company, like SEDE (Veolia) and Lyonnaise des Eaux. The collecting of green waste can also be delegated to a professional company. The responsibility for green waste is transferred to the platform of composting once they are accepted by the platform. It is the same for the co-compost of sewage sludge and green waste. The municipalities rarely think about "closing the loop of nutrients", but simply to get rid of their wastes. The waste producers are in fact the stakeholders directly concerned by the problem of managing outlets of urban waste.

(2). Neighboring problems

Waste producers include the plants and composting platforms that process the urban waste and also intermediate enterprises that facilitate the reuse and management of urban wastes. Waste producers have also neighboring problems.

Wastewater plants of the central agglomeration are extremely large; the technic of biofiltration can efficiently reduce the odor nuisance. The 6 biggest wastewater plants of Ile-de-France have adopted this technology. The composting platform of green waste in the Plateau de Saclay prefers making dry compost because in a wet environment, the compost switches to anaerobic fermentation and results in an offensive odor. Neighboring problems also make the storage and transportation of urban waste troublesome. Some waste managers try to avoid the roads across urban area when transporting urban waste to agricultural lands.

(3). Internal factors of waste producers

Internal factors of waste producers are also important. All the municipalities are waste producers. A small municipality in the rural area has a small plant and normally has no difficulty to evacuate the sludge locally (Aznar et al., 2005). For the plants of intermediate size, the perimeter for land application is within 20 ~ 30 km surrounding the plants. Then, huge plants have the need and capacity to evacuate their sludge to remote rural areas beyond the limits of Ile-de-France Region. The biggest plant Seine-Aval is a typical example. It produced 34% of the sewage sludge of Ile-de-France during 2010-2013 and has a vast area for authorized sludge application as Fig. 7-7 shows.

The technics and equipment of a wastewater plant also determine the characteristics of the sludge, which may be limiting for a certain choice of outlet. For example, when the plant of Plaisir cancelled the drying process because of the high cost for energy use, the pasty sludge became less attractive to local farmers and the plant has turned to co-composting by delegation to a professional company.

As for the composting of green waste, different types of producers exist, including the professional companies of green waste management, professional companies of multiple waste management and farmers who manage a platform for complementary income. Managers of multiple waste are the most possible to do co-compost. Farmers owning a platform commonly use the compost products in their own lands.

The perceptions of the waste producers also matter. None of the four green waste composting platforms in the Plaine de Versailles and the Plateau de Saclay works on co-composting of green waste and sewage sludge, because of the heavy administrative procedure of co-composting and their doubts on the safety of sewage sludge. The co-composting platforms of the big companies are all located outside Ile-de-France.

(4). Feasibility of substitute strategies

The substitute outlets of sewage sludge include landfilling, incineration, composting, methanation and others. Landfilling should be limited. Agricultural land application is the cheapest but the most strictly controlled. Incineration and methanation are interesting in producing energy but are more expensive. Composting with green waste is especially interesting for those who also manage the compost of green waste. They can offer a price reduction to the municipality from 25 euros/t to 10 euros/t for the treatment of green waste by turning to co-composting. The co-compost is then sold for 5 to 10 euros to farmers.

The big producers have commonly shown interests to a mixed strategy of land application, composting and energy production. The mixed strategy is meaningful to deal with accidental situations such as a strike of the transporters or traffic jams because of important activities. The mixed strategy also reduces the need of storage for the periods when land application is not allowed by the regulations. Especially for the municipalities engaged in the Agenda 21, recycling sewage sludge for energy production can effectively reduce their greenhouse gas emissions. The system of "cogeneration" is promising by using the energy produced by incineration or methanation of sewage sludge to dry the sewage sludge for land application. The drying process needs around 900 000 kWh for one ton of evaporated sewage sludge. The "cogeneration" system can reduce that cost.

From 1990s, the proportion of agricultural use (land application and composting) is always around 60% of the sewage sludge produced in France, but land application dominated in the 2000s and now composting is rising. It's not interesting to mix sewage sludge with municipal solid waste, because the two types of wastes have different physical forms. The mixture will have the status of waste and be controlled by strict regulations because of sewage sludge. The managers of wastewater plants pay around 45 ~ 60 euros/t to the intermediate companies for the treatment of sewage sludge. When the sewage sludge managers turn to composting, they are capable to offer a lower price for the treatment of green waste. Potentially, there will be a problem of competition between the co-composting platforms and the platforms of green waste. Now, the tax for green waste treatment is 29 ~ 45 euros/t.

2.1.2. At the scale of local area

The scale of local area can be a municipality, a group of adjacent municipalities or an area like the Plaine de Versailles and the Plateau de Saclay, organized by an association dedicated to cooperation between multiple stakeholders. The motivation to improve territorial cohesion has resulted in initiatives that integrate the side of fertilization and the side of waste eliminating. The authorized plan for sewage sludge application of the wastewater plant of Plaisir was the result of such an initiative.

Plaisir is a municipality in the Plaine de Versailles. Its land use is composed by urban area (50%), forest (25%) and agricultural lands (25%). The plant called "Le-Val-des-Eglantiers" is in charge of wastewater treatment of Plaisir and 1/3 of the neighbor municipality Les-Clayes-sous-Bois. The sludge from this plant was used in remote areas before 2002. A new authorized plan for land application in local area was established in 2002 led by the former mayor of Plaisir. The mayor was also a farmer. He succeeded in finding another nine farmers and introducing thus 3000 ha in total agricultural lands surrounding the plant of Plaisir to be engaged in the plan.

The plant produced 700 t of sludge in the form of pellets each year. The sludge was dried by a gas dryer and the degree of dryness reached 90%. It had a good looking, with little odor nuisance and was well accepted by farmers. The sewage sludge was applied from August to October based upon a 5-year rotation.

However, since 2012, the wastewater plant has been delegated to another bigger company. The sludge now is only partially dried to a degree of dryness of 20% in order to facilitate the transportation to a co-composting platform outside Ile-de-France. The farmers surrounding the plant thus stopped land application of sewage sludge. We interviewed the ex-mayor. He explained the idea to link the farmers with urban population in a local scale. He thought that land application of sewage sludge was a service provided by farmers to urban population. Farmers should be compensated for that.

The case of Plaisir is particular, because the leader of the initiative was the mayor, who himself was a farmer. Usually, the municipal authorities do not have close relationship with the farmers. They represent the interest of the urban population and have a primary objective to get rid of the wastes. But at least, the case of Plaisir suggests that when there is local production of urban waste, it’s always possible to see initiatives for territorial cohesion regarding urban waste recycling because of this or that particular factor.

In an area like the Plateau de Saclay, the wastewater is collected and treated by SIAAP. There is no production of sewage sludge in the area, and the farmers do not use sewage sludge. However, the platform of green waste compost in this area plays the role to improve local recycling of urban waste. The owner of the platform is also a farmer in the area. He considered that his work was a service to the collectivity. More and more farmers began to use the compost following his example on his own lands. Similarly, the platforms of green waste compost in the Plaine de Versailles also had the idea that they provided a service to the collectivity in helping to close the loop of nutrients in the local area.

The associations dedicated to territorial cohesion of the Plateau de Saclay and the Plaine de Versailles, namely, the Terre & Cité and APPVPA, respectively, are important leaders of initiatives that improve the local recycling of urban waste. The Terre & Cité has contributed strongly to the mutual recognition between different farmers in the Plateau de Saclay, among them, the platform of green waste compost. Terre & Cité now is working on a detailed inventory on the availability of organic waste in the area, which will hopefully promote the relations between waste producers and farmers, the users of organic fertilizers.

2.1.3. Regulations at superior scales

The stakeholders at superior scales are defenders of public interests of higher scales, for example, the security of food products in the markets, environmental issues at landscape scale or regional scale, etc. These stakeholders do not have the right to directly intervene the production and recycling of urban waste. Their influences are delivered in the form of regulations. The highest level is the European directives, followed by the French decrees and orders. The regional authority of Ile-de-France has also the regional master plan for the management and eliminating of urban waste. Overall, the regulations can be distinguished into three categories.

The first category includes the regulations on environmental and health risks of fertilizer use in agricultural lands. A big problem linked to the fertilizer use of agriculture is the non-point source pollution. The European Directive of Nitrate is for the purpose to limit nitrogen leaching. All the fertilizers should respect the limit of 170 kg nitrogen per hectare per year. And for the health risks, the “safest” solution would be to prohibit urban waste use. That’s what has happened to sewage sludge in organic farming. From the regional level to the European level, the policy-makers encourage the development of organic farming.

The second category includes the regulations on environmental and health risks of urban waste eliminating. The European directive 91/271/EEC requires that all the urban agglomeration of over 2000 inhabitants should collect and treat their wastewater; the primary target is to reduce constantly the content of micropollutants in the water back to natural environment. Land filling of urban waste is limited. Incineration, composting, methanation and other technics are encouraged. The Ile-de-France Region has the master plan (PREDMA) for the elimination of household and similar wastes.

The third category includes the regulations that aim to improve the mutual relations of waste eliminating and organic fertilizer use. The regulations have set up the thresholds of heavy metal elements in the fertilizer and the soil (86/278/EEC and the French Decree of 1997 and the Order of 1998). The French authority has established a complicated controlling system for land application of sewage sludge (authorized plan of land application, analysis, follow-up, ...), and less complicated systems for the co-compost of sewage sludge and the compost of green waste. The objective is to guide and improve the agricultural recycling of urban waste, but the results are not in perfect accordance with the expectations. Land application is withdrawing from the outlet strategy of sewage sludge because of the heavy administrative procedure and the negative image enhanced by the strict controls on sewage sludge.

2.1.4. Interscale influences

Regulations have strongly influenced the relationship between farmers and waste producers at individual scale. The regulations become progressively strict for the prevention of environmental and health risks. Waste producers and farmers both felt growing pressures from the above level, in waste processing and fertilizer use, respectively. The sewage sludge has been dropped from the list of fertilizer “product”. The heavy administrative procedure is an important reason for the shift from land application of sewage sludge to composting, especially in the plants of intermediate size.

In turn, the regulations at superior scale seem to have little response to the local problems regarding land application of sewage sludge. It’s not sure if the system based upon the authorized plan and an annual report of follow-up is the only or best way to control the risks linked to land application of sewage sludge. Some farmers also worry about the possibility that waste producers would mix unqualified sewage sludge with compost to avoid the limitation of regulations, though this is not allowed legally. So there is a credibility gap between waste producers and farmers.

However, some waste managers told us that they had good relationships with farmers who applied their sludge for 20 years. They have mutual trust between each other. This fact suggests that besides the step-by-step control on the practices, other social factors are also important for improving the trust between waste producers and farmers.

The initiatives for territory cohesion at the scale of local area have positive influences in improving agricultural use of urban waste. Agricultural use of urban waste is considered as a service to urban population and the farmers themselves also receive certain agronomic benefits. These initiatives can enhance the mutual understanding between waste producers and farmers.

In turn, the choice of an individual can either enhance or diminish the local recycling of urban waste. Taking the plant of Plaisir as an example, when the municipality changed the strategy of wastewater treatment, the sludge is sent to remote areas and the local relationships were cut off.

Farmers and waste producers are linked through the flow of urban waste use at individual level. Farmers are independent with the sanitation organization in the same municipality in peri-urban area of Ile-de-France. Interruption of the local relationships may be a common phenomenon in the peri-urban area.

The regulations at superior levels focus on either the side of waste eliminating or the side of fertilizer use. Regulations are short in integrating the two sides of fertilization and urban waste eliminating.

2.2. Categories of farmers regarding urban waste use

This section analyzes the different categories of farmers according to their practices and perceptions of urban waste use in the Plaine de Versailles and the Plateau de Saclay. This category is made only for distinguishing the 18 farmers we met in the interviews (15 in the Plaine de Versailles and 3 in the Plateau de Saclay, see section 3 in Chapter 6 for detailed information of the farmers). All the farmers were doing “Grande Culture” when interviewed. Main crop types included rape, wheat, corn, protein crops and others. The objective is to identify the factors that have actually influenced the choice of farmers, rather than to give a typology for all the farmers in the two areas. It’s possible that other categories of farmers exist.

The analysis identifies 7 categories of farmers (Fig. 7-12).

(C1): Sewage sludge users

The three farmers in this category were engaged in the sewage sludge application plan of the wastewater treatment plant of Plaisir. The plant has changed strategy since 2012, and their sludge is sent to a compost platform outside Ile-de-France as discussed above, so these farmers now do not apply sewage sludge anymore. They have good recognition of the fertilization effects of sewage sludge. They consider themselves as providing a service to urban population when they applied the sewage sludge of Plaisir. They were paid by the plant of Plaisir for additional work after the sludge application, for example, to bury immediately the sludge for avoiding odor nuisance in bad weather. Some of them also used horse manure and green waste compost as complements.

(C2): Shift from sewage sludge to green waste compost because of strong opposition

One farmer in the Plaine de Versailles turned to green waste compost (compost of Plaisir) 2 years ago after 25 years of sewage sludge use because of strong opposition from the people around. He provides service to waste producers for spreading waste into agricultural lands. He works on different kinds of wastes, including sewage sludge, green waste compost, animal manure and other waste originated organic products. So he knows well the characteristics of different wastes. For his own lands, he favored sewage sludge for its fertilization effect free of cost and safety under strict control. But he was alone in the municipal council to vote for sewage sludge application in a conflict three years ago. So he had to abandon the sludge and turned to green waste compost. He told us that it became more and more common in the peri-urban area that the municipalities prohibited sewage sludge application.

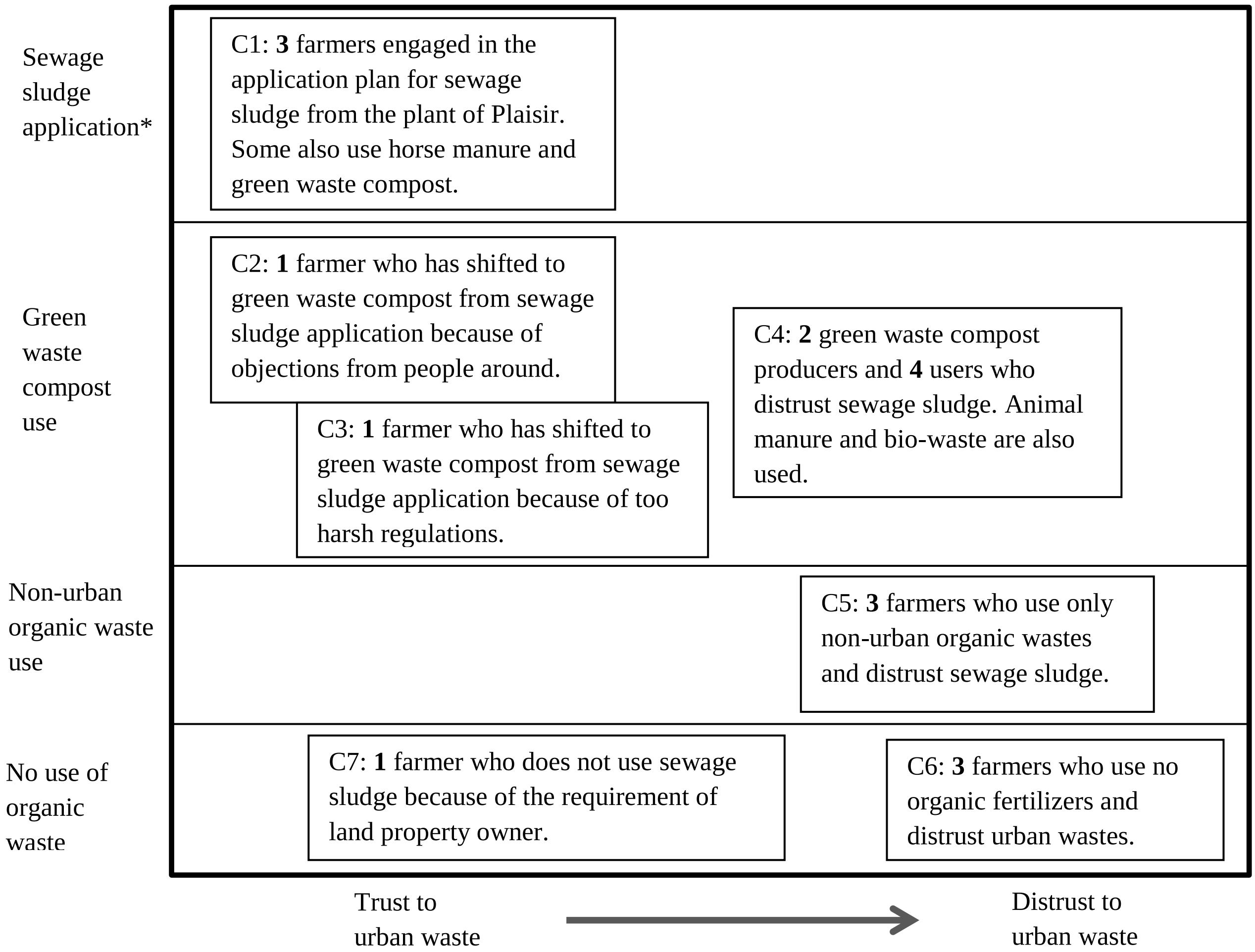


Fig. 7- 12. Principal categories of farmers according to use and perceptions of urban waste. Among the 3 farmers in the Plateau de Saclay, 2 farmers are in Category 4, including 1 producer and 1user of green waste compost; another one is in Category 7. All the other farmers are in the Plaine de Versailles.* the plant of Plaisir has cancelled land application of sewage sludge in 2012.

(C3): Shift from sewage sludge to green waste compost because of too harsh regulations

Another farmer in the Plaine de Versailles stopped sewage sludge application in 2000 because he thought the regulations are too harsh. He showed the willingness to take sewage sludge again if the regulations could be simplified and the wastewater plant took full responsibility of sludge application. It has been already a reality that sewage sludge producers take full responsibility. This farmer may be not very interested by sewage sludge. He mentioned his distrust for the risk of heavy metal pollution. In fact, he was considering converting to organic farming, and in that case, sewage sludge is of no interest because it’s prohibited in organic farming.

(C4): Green waste compost producers and users who distrust sewage sludge

This category first includes two producers of green waste compost, one in the Plaine de Versailles and one in the Plateau de Saclay. They produced a big quantity of compost for their own lands, and the service of composting provided a complementary income.

The others of this category are farmers who take green waste compost, among which, one is in the Plateau de Saclay, 3 are in the Plaine de Versailles. Besides the “Grande Culture” of wheat, rape, corn and others, some of the farmers also worked on vegetable cultivation or organic farming. Some of them took animal manure, bio-waste from a canteen, or co-compost of green waste and animal meal as complements.

Neither of the two composting platforms worked on co-compost of green waste and sewage sludge. None of the farmers used sewage sludge. Farmers in the Plaine de Versailles clearly showed their distrust to sewage sludge. One had personal experience of lands being polluted by sewage sludge application and another said agriculture should not be a rubbish bin of the city. Farmers in the Plateau de Saclay did not show strong emotion against sewage sludge since they did not have sewage sludge production in the area. These farmers considered that the production and use of green waste compost were mutually beneficial for them and the city.

(C5) Users of non-urban organic wastes who distrust sewage sludge

The three farmers in this category are in the Plaine de Versailles. They used only non-urban organic wastes, such as chicken manure, horse manure, and others, produced by their own farm or imported from a nearby farm and even the Region of Brittany. One of the farms was doing organic farming, so he used no mineral fertilizer or urban wastes. The other two mentioned their distrust to sewage sludge because of heavy metals.

(C6) Farmers who use no organic fertilizer and distrust urban wastes

Three farmers in the Plaine de Versailles are in this category. They did not use organic fertilizers. They had distrust to urban wastes, especially sewage sludge because of the risk of heavy metals and odors nuisance. One of them use to take two times sewage sludge but stopped 5~6 years ago. Difficult to manage the mineralization process of organic fertilizers was also the reason why they did not use organic fertilizer.

(C7) No use of sewage sludge because of land property owner

One farmer in Plateau de Saclay did not use sewage sludge because the land property owner required not to. He worked on direct seeding, and integrated leguminous plants in the crop succession to fix nitrogen. He did not use compost for lacking of labor and unwillingness to increase the cost.

Therefore, this classification reveals the relationships between farmers’ perceptions and farmers’ practices regarding urban waste use. Farmer’s choice about using or not urban wastes depends on farmers’ perceptions and also external factors.

When the farmer does not trust urban waste, he won’t take it. They are not compelled to take urban waste because of a certain economic reason, different from the peri-urban farmers in developing countries. The farmers investigated here have most trust to animal manure, followed by green waste compost and sewage sludge at last. Those who take sewage sludge also take green waste compost and animal manure for complement. Some of them abandoned sewage sludge and turned to green waste compost.

When the farmer has a good willingness to accept sewage sludge, external factors result in abandonment of sludge application. These external factors can be change of strategies of wastewater plant (C1), opposition from the residents (C2) and administrative reason (C3) and opposition from land owner (C7).

Among the 3 farmers in the Plateau de Saclay, 2 farmers are in Category 4, including 1 producer and 1user of green waste compost; another one is in Category 7. As there is no local production of sewage sludge in this area, the famers do not have appreciation or strong opposition to sewage sludge. To the contrary, farmers in the Plaine de Versailles demonstrate all kinds of attitudes, from sewage sludge taker (C1 and C2), to those who use no organic fertilizer and don't trust urban waste at all (C6). The influences of multiple factors are more visible.

Though among the farmers in this study, no one use sewage sludge anymore because of external factors or distrust, farmers of C1 commonly exist in the Plaine de Versailles, according to the study of Dhaouadi (2014). Their relationships with the plants may be different from in the case of Plaisir. For example, usually, the farmers do not pay for the sludge nor are paid by plants. The case of Plaisir is particular in that the plant paid farmers for additional work linked to sewage sludge application.

In the peri-urban area, abandonment of sewage sludge use because of external reasons (C1, C2) may increase in the following years. The opposition from land owners against sewage sludge may be an important influence in Ile-de-France, because most of the farmers are not land owners (see Chapter 2 and Chapter 3). The higher trust to animal manure than to urban waste may be partly a result of the encouragement in the commercial policies of some cereal cooperatives in Plaine de Versailles (Dhaoudi 2014). For those who take green waste compost but do not trust sewage sludge, other urban wastes, like organic residual waste compost, digestate of methanation may be interesting. This is because their distrust to sewage sludge came from, to a great extent, the negative image of sewage sludge after a long history, especially the incident of Achères, which is hard to change despite of the improvement in sludge quality. At last, for the famers who totally rely on mineral fertilizer (C6), the growing awareness for the dramatic loss of organic matter in the soil may change their attitudes.

Conclusions

This part used a multiscale approach to investigate the influences on the supply-demand relationship of agricultural recycling of sewage sludge and green waste compost in Ile-de-France. It includes a regional pattern analysis and investigations on local perceptions of different actors.

The first part was dedicated to analysis on the regional pattern of sewage sludge production and distribution of agricultural lands suitable for sludge application according to the limitations of regulations. It is found that the production of sewage sludge spatially mismatches with the distribution of suitable agricultural lands. 90% of sewage sludge production originates from the central agglomeration but the majority of suitable agricultural lands of the region are located in the rural area. Especially in Seine-et-Marne, the area that has received sewage sludge application represents only a small proportion of suitable agricultural lands.

Estimation on crop succession pattern suggests that the classic three-year rotation system of “Fallow-Wheat-March crop” from 16th to19th century in Ile-de-France has had fundamental influences on the modern succession systems. The actual succession systems are more diversified and can be concluded as “Head-Wheat-March”, for which, the “Head” crop can be rape, corn, industrial crops and protein crops. Rape is commonly adopted. Since the year of “Head”, especially rape is the period favorable for sewage sludge application. Availability of agricultural lands is not a problem for sewage sludge recycling at the regional level.

There are two kinds of spatial flows of sewage sludge from wastewater plants to Seine-et-Marne: (i) towards vast rural areas in the east of Seine-et-Marne, (ii) to the municipalities surrounding the plants. Bigger plants tend to send their sludge to farther areas, while smaller plants rely more on the geographical proximity. The biggest plants, like Seine-Aval of SIAAP in charge of the central agglomeration apply majority of their sludge in remote rural areas outside Ile-de-France since long time ago. The plants in secondary grade (10 000-100 000 PE) adjacent to the limit of SIAAP in the western part of Ile-de-France have to turn from land application to co-composting outside Ile-de-France.

Field studies at local scale have confirmed the withdrawing of sewage sludge application in peri-urban area in the western part of Ile-de-France, but also revealed the opposite trend of green waste compost, which is becoming progressively popular.

A framework is proposed to conclude the multiscale influences on the supply-demand relationship in agricultural recycling of urban waste. The key of the framework is the balance between the demand of urban waste for fertilization effects and the demand of waste eliminating. Factors that influence on the balance include those at individual scale, local area scale and regulations at superior scales. At local scale, pressures from food industry, neighboring problems, internal factors and substitute strategies are the factors that influence on the practices of farmers and waste producers. At the local area scales, initiatives aiming at the improvement of territorial cohesion promote the conciliation of fertilization and waste eliminating. The regulations at superior levels focus on either the side of waste eliminating or the side of fertilizer use, and lack efficiency in integrating the two sides of fertilization and urban waste eliminating. These factors at different scales interact.

At last, a classification of seven categories of farmers reveals the relationships between farmers' perceptions and practices regarding urban waste use. When the farmer does not trust urban waste, he is not compelled to take it because of a certain economic reason. Among the organic fertilizers, the farmers have the most trust to animal manure, followed by green waste compost and sewage sludge at last. When the farmer has willingness to accept sewage sludge, external factors result in abandonment of sludge application, including the change of strategies of wastewater plant, opposition from the residents, administrative reason and opposition from land owner.

General discussions

1. An integrated framework of MFA and ES for peri-urban agriculture

1.1. Value of the integrated framework for peri-urban agricultural research

This dissertation proposes an integrated framework of MFA and ES, which identifies MFA based upon the contributions of agro-ecosystem, i.e. ecosystem services, and the role of farmers in transferring or not the ES as functions of agriculture. Identification of the four big categories of function/ES combinations helps to give more precision to MFA and improve the practicability of ES.

The integrated framework makes explicit the mechanisms that support the multiple agricultural functions. ES cascade explains how ecosystem structures and processes (e.g. soil structure and biodiversity) contribute to the delivering of final ES (e.g. food, water and landscape amenity). Environmental functions can thus be strongly justified. Now the growing awareness of farmers for the negative impacts of over using mineral fertilizers makes them to reconsider animal manure or green waste composts. Many hesitate for that it is complicated to match the fertilization effects of organic fertilizer with the crop needs especially at the beginning of the crop cultural cycle. In fact, the fertilization effects of organic fertilizer rely on contributions of the microorganisms in the soil, that is to say, an ES. Understanding the mechanism that provides this ES allows the control of the process.

Construction on an agricultural land usually means permanent loss of associated ecosystem services, because it is hard to keep the original ecosystem on the lands. Reconstruction of an agricultural system is more than the establishment of agricultural activities and depends on the available means as well as the local policies: that explains the difficulties in returning abandoned lands to agriculture in peri-urban areas. As Chapter 2 shows, the extensive peri-urbanization in the 1960s-1970s in the Ile-de-France Region resulted in massive land abandonment. Agricultural lands became marginal in these areas and have never recovered. Therefore, urban planners should be cautious and avoid the waste of agricultural lands.

In turn, this framework integrates the role of social economic structure. Improvement of provisioning ES of food and materials does not necessarily increase the function of food supply and economic return. ES studies usually deal with the problem of trade-off/conciliation among production and environmental protection (e.g. Viglizzo and Frank, 2006; Maes et al., 2012). They try to end with a dilemma that either restrictive environmental regulation becomes an obstacle to farmers, or the payments for environmental friendly practices are marginally attractive. Organic farming has on average 25% less productivity than conventional intensive agriculture (Seufert et al., 2012). Nevertheless, productivity itself is not the final target. This is neglected for a long time and the agriculture in Ile-de-France is locked in a "path-dependency" on a productivist regime (Lamine et al., 2010):

The productivity of cereal crops in Ile-de-France increased persistently in the last century, but the economic revenue per hectare recently decreased. With the support of agricultural mechanization and policies, farmers relied on continually enlarging the farm size to maintain the profitability of cereal crops. However, it is found that direct aids to a farm of "Grande Culture" exceed sometimes their revenue from production (Chatellier and Baudry, 2009). When the economic situation of the large-size cereal crops becomes more and more delicate, what farmers need to do is not persistent on increasing their productivity or enlarging the farm size, but to adjust their economic models.

1.2. The remaining question of defining ES and agricultural functions

Defining ES and MFA is both highly controversial. Disputes around ES principally arise over the differentiation between functions, services, and benefits, which result in different classification systems (see Chapter 1). MFA is long been criticized for lacking of precision in defining the functions (Garzon, 2005), but some scholars consider that as an advantage to cover a wide range of contributions from agriculture (Caron et al., 2008).

The four categories of agricultural functions in the integrated framework of MFA and ES are not exhaustive. The objective was rather to demonstrate the idea of relating MFA with the underpinning ES, or, more accurately, relating agricultural functions with the benefits from agro-ecosystems and its surrounding natural habitat, since the definition of ES is still in debate. The remaining question is how to integrate the various agricultural functions discussed in the literature with the framework. I discuss with the research in France as an example:

Aumand et al. (2006) reviewed the definitions, references and interpretations of MFA in France. They identified six research streams of MFA, namely, (i) joint production of commodities and externalities/public goods from agriculture; (ii) multiple impacts and contributions of agriculture to society, local communities and environment; (iii) agricultural multifunctionality as a complementary and conflicting connection between commodity and identity goods; (iv) farmers' strategies and practices; (v) social demands towards agriculture; (vi) roles of agriculture to be officially addressed by policies.

Among the functions listed in these researches, it is easy to identify the underpinning ES for commodity goods and environmental externalities/public goods, as demonstrated in the framework of Chapter 3. It is more challenging for the social cultural functions, such as maintenance of territorial identity or social tie, contributing to vitality of rural communities, improving social equality and others. Territorial identity or rural vitality can be established on an agricultural product, the landscape, a tradition or the combination of all these elements. The linkage of MFA and ES is not fixed, neither. When a farmer turns to agro-tourism, the landscape amenity ES also contributes to his economic return. For peri-urban agriculture, an example often heard is the function as a barrier to urban extension. This is the most difficult to explain with ES. Possibly the peri-urban population do not want to live in an urban environment, so they choose to protect the agricultural lands and enjoy the benefits from the agricultural landscape.

Therefore, the discussion leads to two suggestions: First, in different areas, the linkage between MFA and underpinning ES is different with geographical areas and also the evolution of an agricultural system. Second, some functions (Level 1) are directly underpinned by the interactions between ES and social economic factors (principally those described in the framework of Chapter 3), and others (Level 2) are results of further interactions between the functions of Level 1 with more social economic factors. Local investigations would be able to clarify the contributions of ES and contributions of the social economic system to the formation of an agricultural function.

1.3. Interaction between the different ES/functions

Tradeoff or conciliation between different ES is an important research topic in ES studies (see Chapter1). The integrated approaches of MFA and ES should also consider the interactions between different ES-MFA. Investigation methods may be different because of having directly considered social economic factors.

Over use of one function will possibly damage others. The example of Ile-de-France (see Chapter 3) shows that pursuit of economic return in the 20th century resulted in marginalization of local food supply, regression of agricultural employment, simplification of landscape and degradation of environmental quality. Furthermore, increasing use of mineral fertilizers has reduced the need of urban wastes, which were widely used for vegetables and cereal crops. In turn, unregulated urban wastewater applications in Triel-sur-Seine, Carrières-sous-Poissy and the Achères Plain in the last century resulted in severe soil pollution, and led to the prohibition of food cultivation in this area. The increasing environmental concerns of farmers also influence on their willingness to take urban wastes, especially sewage sludge, though the regulations have been greatly improved in limiting the risk of sewage sludge to environment and health.

The interactions between different ES/functions also provide opportunities for the preservation of peri-urban agriculture. Local food function is important only when the food has higher quality or traceability. Darly (2012) found that the mutual confidence between producers and consumers based upon geographical and social proximity could drive an initiative of organic farming. Aubry (2012) also pointed out that organic vegetable cultivations in the Ile-de-France Region were all sold in short supply chain. The recreational function of agriculture cannot be replaced by forests or urban parks when it combines with the function of local food supply and the value of agriculture as a lifestyle. The charter of Vexin PNR set out from an intention to maintain agricultural landscape against urbanization, but also brought agreements on the protection of natural flora and fauna, and actions against soil erosion (Poulot, 2010). Daniels (1986) pointed out that hobby farming in favor of city dwellers may threaten local productive agriculture. However, in Ile-de-France, family gardens now also provide the food function (Pourias, 2014). It is thus interesting for future study and policy making to investigate on the combination of local food, short supply chain, organic farming and agro-tourism.

2. Considering the mutual relations between land use and ES/MFA

2.1. Mutual action between land use and ES/MFA

Many ES studies investigated the influences of land use change to ecosystem services (e.g. Polasky et al., 2011; Mendoza-González et al., 2012; Bateman et al., 2013). The origin of this tradition could be traced to the monumental work of Costanza et al. (1997) valuing ecosystem services from different land use types at the global scale. The objective of such studies is to identify the land use types or practices that should be protected in order to maintain the provisioning of certain ES. Because non-commodity ES, such as those concerning environmental integrity, lack markets, so usually it’s difficult to motivate the modification of land use or practices (Robertson and Swinton, 2005; Ribaudo et al., 2010).

Combining the concept of MFA with ES makes it possible to consider the mutual relations between the land use changes and ES/functions. Social demands for selective agricultural function result in particular land use pattern, which in turn impacts on the delivering of multiple ES. ES are the fundamental support of agricultural functions. The change of ES will finally influence on agricultural functions, and make people to rethink about their practices. It is just that social demand for particular agricultural functions also depends on other factors, such as personal attitude and policies. The reaction of social demand to the change of ES may need a long time. For example, the level of organic matter is decreasing in the soil of Grande Culture in Ile-de-France, but the farmers are not affected in a short term. The evolution of the regional land use policies of Ile-de-France reveals the mutual interactions between land use changes and ES/functions.

In Ile-de-France, the function of food supply to the city center became less important because of the increasing exportation and importation of agricultural products. In 18th century there were even laws to prohibit food exportation in particular period (Weulersse, 1910). Then exportation was highly encouraged by governors, in the Plan of Monnet after the Second World War as well as the Common Agricultural

Policy of European Union since 1960s. Pursuing economic return became the primary concern of agricultural activity, especially when land leasing became the main form of exploitation (Weulersse, 1910). Consequently, peri-urban agriculture went into the process of intensification and simplification, especially in the 1960s and 1970s.

Then, the master plan (SDRIF) of 1976 recognized for the first time the landscape support function of agricultural lands. The master plan of 1994 confirmed the recognition of “Green Belt (Ceinture Verte)” as an important amenity for the Region. The new master plan of 2013 reclaimed the function of food supply to the city center, consistent with the Regional Food plan and asked to strengthen the role of agriculture in biodiversity conservation. Since 1980s, loss of agricultural lands became much slower. And after 2000, organic farming, community supported agriculture and other short supply chains developed rapidly. The oversimplified agricultural structure began to be questioned. Factors that drove this evolution include not only the spontaneous change in the social concerns, but also the feedback from the degraded environmental quality and simplified landscape.

2.2. The mutual acting mechanism between land use and ES/function in the management of abandoned farmlands in peri-urban areas

In Ile-de-France, farmland abandonment is an important issue in the peri-urban area (Chapter 5). In urban area, land abandonment is linked to urbanization, especially in the New Towns and the pole of Airport CDG. Though urbanization slowed down from 1980s, the following lands are still in high risk of abandonment: residual agricultural lands enclosed by urban areas or between urban area and forests, and lands cut up by extensive constructions and infrastructures. In rural area, the reasons of land abandonment are usually linked to poor agronomical conditions such as destruction by sand mining, instability when cultivating wetlands in the valleys, soil pollution, and poor soil quality in the forests area.

Therefore, in this process, only the function of agricultural production has been considered. Farmlands are abandoned when their agronomic value are not interesting. When massive abandonment happened in the peri-urban area in the 1960s-1970s, the society had little recognition for landscape function of agriculture or other environmental functions such as the contribution to biodiversity ?.

The ES and functions of the lands change after the abandonment. In rural area, since land abandonment usually happens near forests or in the wetland, abandoned lands evolve quickly towards natural habitat. In the urban area, the abandoned lands become a green space for the residents. The problem of illegal waste dumping and camping also changes the state and social image of abandoned lands.

If abandoned lands are primarily destined to construction, the biophysical state of the lands may be not important. However, the actors interviewed in this study are overwhelmingly against urbanization on abandoned farmlands. The social expectations towards these abandoned farmlands are mainly recreational, environmental and agricultural functions. As for the reuse of abandoned farmlands, people who are primarily concerned by environmental functions also prefer agricultural use. They expect an alternative form that is environmentally friendly for biodiversity, wildlife, and others. In the PNR of Chevreuse, some farmers and the manager of PNR are working on that. They regularly maintain the lands to avoid the “invasion” of forests.

Therefore, it suggests a social expectation for multifunctional agriculture. The process from farmland abandonment to development of multifunctional agriculture is the result of a mutual acting relation between land use and ES/functions. Abandonment allows the land to develop a different bundle of ES and functions, which makes the people around to realize the multiple benefits from the lands.

3. Mutual services between actors in agricultural recycling of urban waste

3.1. Mutual services between farmers and waste producers in the agricultural recycling of urban waste

Agricultural recycling of urban waste is a mutual service between the waste producers and farmers, especially in land application of sewage sludge (see Chapter 7). When sewage sludge has good quality and well supervised, the two actors can have a win-win relationship. For wastewater plants, agricultural land application is the economically best choice for evacuating sewage sludge, comparing to composting, incineration and the future methanation. For farmers, sewage sludge is free of cost and interesting in replacing at least partly mineral fertilizer for supplying nitrogen and other nutrient elements. Green waste compost, to the contrary, is interesting for long term effects to improve soil organic matter and ameliorate soil structure. Green waste compost alone is not enough for replacing mineral fertilizer. The actual principles of free sludge for farmers and waste producers having full responsibility are appreciated by farmers and acceptable for waste producers.

Noteworthy is that urban population is the real origin of sewage sludge, but is rather against agricultural recycling in the peri-urban area of Ile-de-France. The sanitation service in the central agglomeration is delegated to professional companies, like Veolia and Lyonnaise des Eaux. The study of Aznar et al. (2005) also revealed that more and more municipalities in the Region of Auvergne chose to delegate sanitation service to a professional syndicate or company to “avoid” the problem of sewage sludge. The problem of sewage sludge does not disappear by delegation; it has just been transferred to the waste producers.

The separation of urban population and waste producer intensifies the opposition to agricultural recycling of sewage sludge. In turn, the difficulties for evacuation of sewage sludge promote the delegation of sanitation service to professional waste processors, and thus result in increasing separation of urban population and waste producers.

Urban population does not care about the outlet of the sewage sludge and even where their wastewater goes. Urban population just needs to pay their water bill for the service of potable water production and wastewater treatment. And it is not a pressure any more to prompt the urban population to be interested in agricultural recycling of sewage sludge.

Therefore, it is not interesting for urban population if agriculture is providing a waste recycling service to the city. Urban population in the peri-urban area who has a fanciful picture of rural life and high requirements on environmental quality will not accept sewage sludge originated from other area. Some peri-urban municipalities prohibit use of sewage sludge.

3.2. Implications to Payments for Ecosystem Services/Environmental Services

For the question if farmers should be paid for accepting sewage sludge, the waste producers have negative response because urban wastes have agronomical and economic value for farmers. farmers also give negative response. They do consider themselves providing a service to the collectivity, but they don’t want to be imposed the responsibility of sewage sludge with the payments. They are satisfied that they do not need to pay anything and the waste producer is in charge of the application. The urban population is in fact the final payer for the service of eliminating urban waste.

This finding leads to interesting suggestions to the instruments of Payments for Ecosystem

Services/Environmental Services (PES), which are popular in ES strategies. PES should not be simply considered as monetary payments to farmers. Instead, the program manager should well understand the relations between different actors, not only in the biophysical dimension but also in the economic and social dimensions.

4. Multi-scale influences and scale mismatch

In a social-ecological system like agriculture, mismatches between the scales of ecological processes and the institutions are responsible for mismanagement of natural resources and decrease in human well-being (Cumming et al., 2006). As for peri-urban agriculture in Ile-de-France, the physio-ecological scales go up from a field, a landscape, a valley or a catchment, until the landform. The institutional scales go up from the farm, the municipality, the inter-municipality, the department, the region, until the national and European level concerning some regulations. The problem of scale mismatching is evident in the region and worthy of attention.

The Common Agricultural Policy (CAP) is faced with what Cumming et al. (2006) called “micromanager syndrome” that EU-level decision-makers micromanage the juniors at a fine physio-ecological scale. It is at least one of the most important factors of the simplification and intensification of agricultural lands (Charvet, 2003). It has resulted “ecosystem over-exploitation”, when most of the local level farmers are producing for the international market.

Similarly, it is challengeable for EU to manage the regional environmental problems such as biodiversity conservation, nitrate leaching, soil retention and others. The Agri-Environment Measures were first introduced into EU agricultural policy during the late 1980s and became compulsory for Member States since the reform of CAP in 1992. Luckily, the European Commission allows that Agri-Environment Measures may be designed at the national, regional, or local level in order to be adapted to particular farming systems and specific environmental conditions.

On the other side, environmental questions are usually beyond the scale of a single farm, so a higher level management is necessary for guaranteeing the ecological continuity and consistency of the environmental process. It is understandable that farmers are not happy to adopt environmental friendly practices which cause themextra costs without bringing them visible benefits. When a local farmer is responsible for a higher level ecological consequence, this corresponds to another case of scale mismatching revealed by Cumming et al. (2006), which may result in disruption of the farmer’s system.

Efficient instruments help to connect the upper-scale benefits with lower-level benefits. Many ES studies shared the idea to create markets for non-commodity ES like biodiversity and climate change (Ribaudo et al., 2010). But the lower-level stakeholders may also appreciate other things than economic revenue. For example, when a farmer understands that biodiversity contributes to the maintenance of soil structure in his farm, he would be more motivated in change his practices. Or, he would be also willing to accept some limitations in order to avoid quarrels with his neighbors who ask for landscape beauty and environmental quality (Bühler and Raymond, 2012).

Development of general indicators to farmers should be cautious. Even for the term of “biodiversity”, there are different understandings, e.g. species richness, richness of varieties, cultivars or genetical expressions (Büchs, 2003). Farmers adapt the EU’s policies according to their particular intention. Thus the result may be different from what expected by the upper-level policy makers (Bühler and Raymond, 2012). Result-oriented measures (Matzdorf and Lorenz, 2010; Sabatier, 2012; Schroeder et al., 2013) may be interesting for regulations on agricultural land management, waste recycling and others.

5. Methodology

5.1. Two in-depth studies

The studies on abandoned farmlands proceeded from a land use type, while the study on urban waste recycling proceeded from a "service". The original intention was to find out the ecosystem services/functions that abandoned farmlands provide to people and the agricultural lands linked to the service of urban waste recycling. Finally it turned out that both are more complicated than what we have expected.

Abandoned farmlands are a particular land use type in continuous dynamic. The related ES and functions are also quite different according to the geographical area and social context. The conversion of abandoned farmlands is not only determined by the ecosystem services they actually provide but also what people expect from their future forms. Agricultural recycling of urban waste is not "a" service, but is related two ecosystem services. Furthermore, the relation between farmers and urban population is mediated by waste producers. Therefore, it suggests that in-depth studies on a particular ES or land use type are meaningful, which can find information neglected in the analysis for valuation and mapping of multiple ecosystem services, especially, the social economic factors.

Comparison between the two studies is useful for formulating conclusions. Abandoned farmlands are also called wastelands, a land without utility, but in fact they supply multiple ES and disservices. Urban wastes are not only wastes, but also fertilizers. Therefore, both abandoned farmlands and urban wastes are resources and wastes at the same time. They both need proper management, because management strategies change the function of these "wastes".

The two in depth studies were carries in four local areas in the west of Ile-de-France. The PNR of Chevreuse is an area driven by environmental concerns. The bench of Seine at Triel-sur-Seine, Carrière-sous-Poissy, and Vernouillet (TCV) is an area polluted by waste water spreading, so does not have important agricultural lands. The Plaine de Versailles (PDV) and the Plateau de Saclay (PDS) are two areas with strong willingness to protect agricultural lands. In PDV and PDS, there was no important land abandonment according to the analysis in Part 2. In turn, the PNR and the TCV is not so interesting for the study of urban waste recycling, because in TCV, lands were polluted because of waste water use in the last century. In PNR, many farmers work on organic farming, for which, sewage sludge use is prohibited.

It is interesting to find out that the four areas close to each other are in such different situations. However, there are also relations between the four areas. The pollution incident in TCV gave a deep image for people in the PDV. The vast abandoned lands in TCV always remind the farmers in the Plaine de Versailles of the terrible history.

5.2. Multi-level approach

This dissertation adopted multi-level approach for the two in-depth studies. The multi-level approaches both include a regional pattern analysis and investigations at local scale with different actors. The results prove that combination of regional pattern analysis and local perceptions is important.

5.2.1. Considering the regional pattern

First, the eastern and western parts of Ile-de-France are quite different. The eastern part is occupied by the department of Seine-et-Marne and remains the largest rural area of Ile-de-France. Correspondingly, abandoned farmlands also have this pattern. Among the New Towns, the Saint-Quentin-en-Yveline in the western part is little touched by land abandonment caused by urbanization, while the New Town Marne-la-Vallée is the area with most striking concentration of abandoned farmlands. The western rural area is mainly occupied by the Forest of Rambouillet, and the PNR of Chevreuse. The eastern part is occupied by the agricultural zone of Brie. The PNR of Chevreuse is the most important rural area touched by land abandonment, while the Plateau de Brie does not have many abandoned farmlands.

Similarly, the pattern of agricultural recycling of urban waste also has this dichotomy. In the department of Seine-et-Marne, vast area of agricultural lands is available for application of sewage sludge. The important wastewater plants in Seine-et-Marne principally output their sludge to municipalities surrounding the plants or in the east fringe of the department. The western part is more urbanized and contains most of the important development centers of Ile-de-France. The population has high requirements on environmental quality and farmers are faced with more constraints imposed by the neighbors and the collectivity. Meanwhile, the polluted area by waste water spreading of Achères is also located in the west; many people including farmers still have strong feelings of distrust toward sewage sludge for fear of pollution by heavy metal elements. Therefore, the peri-urban plants having problems for evacuating their sludge are located in the west.

Therefore, in Ile-de-France, the eastern part is mainly dominated by rural characteristic, composed by agricultural lands. The western part is composed by forests, urban development centers (OIN Seine-aval, Saclay…), agricultural lands, environment protection zone, and is thus concerned a complicated interactions among different actors.

Investigations at local scale should at least consider this regional pattern. It is also interesting to compare between these two parts, which may formulate useful suggestions for the land management in Seine-et-Marne and prevent the problems encountered by the western part before.

5.2.2. Inconsistence in the results between regional study and local investigations

The inconsistence in the results between regional study and local investigations helps to identify the problems in the data for regional analysis or in the methods for local investigations. For example, the analysis on MOS at the regional level in Chapter 2 shows that the conversion from arable lands to meadows/fruit lands is the most important land use change type from 1982-2012, and the opposite conversion from meadows/fruits to arable lands is much less. Nevertheless, arable lands should have increased in that period because of the subsidies of CAP to “Grande Culture”, according to the local experience.

The reason for that inconsistence may be a problem of the statistical data (for example the scale of these data), but can also be a wrong impression at the local scale.

Another example is about the existence of abandoned lands. At individual level, the perceptions of actors depend on their personal experiences. When people do not have abandoned lands around, they think the subject is not important in the PNR of Chevreuse for example. People live in Triel-sur-Seine, to the contrary, may overestimate the existence of abandoned lands in the region.

Therefore, it’s interesting to verify the reasons of the inconsistence in the results between the regional study and local investigations. If it is a problem of the statistical data, at least it can help improve the methods of data collecting.

6. Operational implications

6.1. Management of abandoned farmlands in peri-urban area

Comparing to reforestation and urbanization on abandoned lands, return to agricultural use is the most in demand, followed by entertainment use. The study thus suggests a social expectation for alternative multifunctional agriculture forms in the peri-urban area, which combine environmental, landscape, recreation and other functions, and adapt to land fragmentation in urban area. In a rural area like PNR, the primary target is to maintain open landscape, while in an urban area like Marne-la-Vallée or Sénart, the primary target is to develop alternative forms that adapt to land fragmentation. The traditional large-size mechanized agriculture does not work with these situations. It should be interesting for farmers and regional policies to think about the transitions towards MFA.

6.2. Improve the system of agricultural recycling of urban waste

The actual principles of free sludge for farmers and waste producers having full responsibility are appreciated by farmers and acceptable for waste producers. The urgent need is to improve communications among different stakeholders including urban population and the primary problem of regulation is to simplify the procedure and offer visible and convincing evidence for the safety of sewage sludge use. Distrust originates from lacking of understanding. Instead of the attitude of "Not in My Backyard", cooperation for better quality of sewage sludge and alleviation of neighboring nuisance create conditions for win-win relations between urban waste eliminating and surviving of peri-urban agriculture. Initiatives for territorial cohesion like those of the association Terre & Cité in the Plateau de Saclay are meaningful. Besides sewage sludge and green waste compost, other urban wastes are potentially interesting for agriculture (see below).

The urban population is the final payer for the service of eliminating urban waste. It would make a difference to let urban population know about their waste. Initiatives of territorial cohesion and even a regional management of urban waste integrating multiple stakeholders are meaningful for both urban waste management and the development of peri-urban agriculture. The focus would be on technics to improve the quality of sewage sludge (including its transformation into a "product" by composting or co-composting) and reduce the nuisance to neighbors instead of distrust among stakeholders.

Besides sewage sludge and green waste compost, there are also other urban wastes potentially usable for agriculture. The most promising are compost of municipal solid waste, bio-waste from kitchen and digestate of methanation. They are better accepted than sewage sludge, so should be interesting for peri-urban farmers. But the collecting of bio-waste is still marginal in Ile-de-France (PREDMA, 2009). Compost of municipal solid waste also represents only a small proportion of the total amount. Selection is important for recycling of these wastes. The facility of methanation is expensive, so the digestates remain projects in planning. Agricultural use of organic wastes has the problem that it is difficult to calculate the fertilization need of crops because the process of mineralization differs according to the characteristics of wastes, soil and climate (Dhaouadi, 2014). So it would be necessary to have expert consultants ready to help and communicate with farmers.

Conclusions

Peri-urban agriculture is in great challenge because of the pressure from urban extension or the expansion of natural and recreational spaces. MFA and ES are two strategies that recognize and manage multiple services and disservices from agriculture beyond food and material production. MFA and ES are closely related and highly complementary. Each has advantages and also shortcomings. However, the two communities that independently focus on MFA or ES have limited interaction and exchange.

This dissertation, with the objective to contribute to integrated approaches of MFA and ES for peri-urban agricultural research, has (i) developed an integrated framework of ES and MFA for peri-urban agriculture based upon a comparative review on agricultural research working on the two strategies and application in the Region of Ile-de-France, (ii) and also demonstrated how the integrated approach of MFA and ES works on concrete problems linked to peri-urban agriculture with two in-depth studies on management of abandoned farmlands and agricultural recycling of urban wastes in Ile-de-France Region, respectively. Multi-scale analyzes were carried out for the two in-depth studies.

(1). The first part developed the integrated framework:

Land use analysis in Ile-de-France revealed that agricultural lands in Ile-de-France Region experienced dramatic changes in the last century, under the joint influences of urbanization, agricultural modernization and agricultural policies responding particularly to a postwar context. Correspondingly, the evolution of agricultural lands distinguishes three periods: the continual urban expansion before 1960s, peri-urbanization and sub-center construction in 1960s and 1970s, and from 1980s when peri-urbanization and sub-center construction slowed down.

The integrated framework of ES and MFA for peri-urban agriculture distinguishes four categories of ES/function combinations. The functions and ES change as following:

The first category includes provisioning ES and related functions. Agriculture in Ile-de-France has an extraordinary provisioning ES but does not contribute much to the local food supply. The average economic return to a farmer has increased remarkably, but the economic return from per unit of land is decreasing in the system of “Grande Culture”. The salary of a worker is increasing but the number of workers is decreasing at the regional level. Farmers rely on the enlargement of farm size to maintain profitability.

The second category includes landscape amenity and cultural ES and related functions. The agricultural landscape in Ile-de-France has been greatly simplified in the process of agricultural modernization, but the open vast fields of “Grande Culture” are appreciated as a symbol of freedom. Agri-tourism is developing fast in peri-urban area. Agriculture is also a lifestyle appreciated by traditional farmers and urban population who cultivate family gardens. Meantime, agriculture plays an important role in building territory identity through Regional Natural Parks, Agri-Urban Projects and other instruments.

The third category includes agricultural recycling of urban wastes and the underpinning ES of waste breaking down and fertilization. In Ile-de-France, urban wastes partly or totally used in agriculture include the sewage sludge, green waste and household organic waste. Multiple factors influence on the supply-demand relation between peri-urban farmers and the urban population regarding urban waste use.

The fourth category includes the environmental functions, which characterize the contributions of farmers to the maintaining of multiple regulating and supporting ES in agro-ecosystem and surrounding semi-natural habitats. Agriculture in Ile-de-France substantially replaced ES with artificial inputs in the last century. This substitution resulted in dramatic degradation of ES and negative impacts to environment, such as degradation of soil fertility, nitrogen leaching, and pesticide drift, as well as the decline of biodiversity. However, comparing to the highly urbanized area, agricultural lands are still in priority for environmental benefits. Various instruments try to encourage farmers to enhance environmental functions, such as the Agri-Environmental Measures, labelling of organic farming, and integration of agricultural lands into the Blue and Green network.

The economic value of agricultural production alone is not enough to stand against the regression of peri-urban agriculture. Integration of ES and MFA strategies will provide strong justifications and effective solutions for the preservation of peri-urban agricultural lands.

(2). The second part is the in-depth study about management of abandoned farmlands:

This part has conducted a multi-level approach to study the problems linked to the management of abandoned farmlands in the Ile-de-France Region. It combines a regional pattern analysis on the location and conversions of abandoned farmlands with investigations at two local areas about the perceptions of different stakeholders.

There are four groups of municipalities and each has a different situation of land abandonment, including two groups in rural area and two groups in urban area:

In urban area, there is one group under strong peri-urbanization and another group of highly urbanized municipalities. The reasons of land abandonment are linked to urbanization. Lands in high risk of abandonment are residual agricultural lands enclosed by urban areas, or between urban area and forests, and lands cut up by extensive constructions and infrastructures. The group under strong peri-urbanization is most concerned by land abandonment. They are mainly composed by municipalities in the New Towns and the pole of Airport CDG.

In rural area, there is one group highly concerned by land abandonment because of non-urban factors, and another group comprised by the rest municipalities with strong rural characteristics. The reasons of land abandonment are usually linked to poor agronomical conditions such as destruction by sand mining, instability when cultivating wetlands in the valleys, soil pollution, and poor soil quality in the forests area. The highly concerned group is comprised by several benches of Seine and Marne, among which the bench including Triel-sur-Seine and Carrière-sous-Poissy have large area of abandoned lands because of soil pollution by urban waste use.

The investigations at local level have studied the perceptions of farmers, habitants, elected representatives and environmental associations about the ecosystem services and disservices of abandoned farmlands. The results suggest differences among the levels of actors and between local areas:

Farmers and habitants at individual level perceive abandoned lands according to their personal experiences, so the knowledge of abandoned farmlands varies widely. The municipal managers, i.e. the mayor, service of urbanism and responsible of associations, have rather an overall image about the location of abandoned farmlands and influences in their municipalities. The managers of the PNR of Chevreuse are even in a higher level and have the duty to coordinate the interests of different actors including farmers, habitants, and others, working on a wide range of interests.

There are convergences and divergences between the actors in the PNR of Chevreuse and the area of

TCV (Triel-sur-Seine, Carrière-sous-Poissy and Vernouillet). Both PNR and TCV recognize the abandoned farmlands as natural and wild spaces, which provide habitats for the wildlife. Such spaces lead to positive feelings, but also bad ones because of the big animals, or the illegal waste dumping and camping. TCV recognizes more the value of abandoned lands in discovering fauna and flora. The PNR does not show a significant interest in the entertainment and esthetic service of abandoned lands. Most of the actors in PNR do not favor the strategy with a pure objective of ecological use. Instead, they would rather support for example agricultural activities combing ecological concerns.

Finally, the hierarchical clustering analysis identified three groups of actors, for which, the determinants are the "Agricultural potentials" (Group 1), "Environmental values" (Group 2), and "Recreational values" (Group 3) of abandoned lands, respectively. Group 1 shows significant willingness for return of abandoned lands to agricultural use. Group 2 would prefer agricultural use for environmental concerns. Group 3 has a high appreciation for entertainment/recreational service of abandoned lands.

(3) In-depth study about the agricultural recycling of urban waste

This part used a multiscale approach to investigate the influences on the supply-demand relationship of agricultural recycling of sewage sludge and green waste compost in Ile-de-France. It includes a regional pattern analysis and investigations on local perceptions of different actors.

It is found that the production of sewage sludge spatially mismatches with the distribution of suitable agricultural lands. 90% of sewage sludge production originates from the central agglomeration but the majority of suitable agricultural lands of the region are located in the rural area. In Seine-et-Marne, the area that has received sewage sludge application represents only a small proportion of suitable agricultural lands. Estimation of crop succession also suggests that availability of agricultural lands is not a problem for sewage sludge recycling at the regional level.

There are two kinds of spatial flows of sewage sludge from wastewater plants to Seine-et-Marne: (i) towards vast rural areas in the east of Seine-et-Marne, (ii) to the municipalities surrounding the plants. Bigger plants tend to send their sludge to farther areas, while smaller plants rely more on the geographical proximity. The biggest plants, like Seine-Aval of SIAAP in charge of the central agglomeration apply majority of their sludge in remote rural areas outside Ile-de-France since long time ago. The plants in secondary grade (10 000-100 000 PE) adjacent to the limit of SIAAP in the western part of Ile-de-France have to turn from land application to co-composting outside Ile-de-France.

Field studies at local scale have confirmed the withdrawing of sewage sludge application in peri-urban area in the western part of Ile-de-France, but also revealed the opposite trend of green waste compost, which is becoming progressively popular.

A framework is proposed to conclude the multiscale influences on the supply-demand relationship in agricultural recycling of urban waste. The key of the framework is the balance between the demand of urban waste for fertilization effects and the demand of waste eliminating. Factors that influence on the balance include those at individual scale, local area scale and regulations at superior scales. At local scale, pressures from food industry, neighboring problems, internal factors and substitute strategies are the factors that influence on the practices of farmers and waste producers. At the local area scales, initiatives aiming at the improvement of territorial cohesion promote the conciliation of fertilization and waste eliminating. The regulations at superior levels focus on either the side of waste eliminating or the side of fertilizer use, and lack efficiency in integrating the two sides of fertilization and urban waste eliminating. These factors at different scales interact.

At last, a classification of seven categories of farmers reveals the relationships between farmers' perceptions and practices regarding urban waste use. When the farmer does not trust urban waste, he is not compelled to take it because of a certain economic reason. Among the organic fertilizers, the farmers have the most trust to animal manure, followed by green waste compost and sewage sludge at last. When the farmer has willingness to accept sewage sludge, external factors result in abandonment of sludge application, including the change of strategies of wastewater plant, opposition from the residents, administrative reason and opposition from land owner.

This study would be valuable for other regions or countries. Different countries have different ecological, social and economic conditions, but experience more or less the same process of urban expansion, peri-urbanization, and agricultural modernization. The integrated framework we proposed could be interesting to be applied in other conditions, and the multiscale approach is meaningful in a large range of situations. The concrete cases of application (here land abandonment and recycling of urban wastes) are also probably generic points, even if their importance and the perception of stakeholders may vary according to the context. Many developing countries would begin the process of sub-centers construction and peri-urbanization in the near future, which has the most dramatic influences on peri-urban agricultural lands, as shown by the case of Ile-de-France. Comparison with these different countries will help to understand their differences and common points in ranking the importance of different functions and find out efficient instruments for the preservation of peri-urban agriculture.

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Appendices

Appendix 1. Publication statistics

We performed publication statistics to examine multifunctional agriculture (MFA) and ecosystem services (ES) research trends. We identified all articles using MFA and ES that were indexed by Web of Science and published from 1975 to November 15, 2013. In order to distinguish the publications involving agricultural problems of each concept, to contrast the publications addressing multiple ecosystem services with that of MFA, and to investigate the publications using both MFA and ES, we classified the publications into eight categories (Table1):

Table 1. Methods and results of the searches for publications on the Web of Science (from 1975 to 2013-11-15)

Publication categories	Methods	Results
ES_all	Topic=(Ecosystem* service) OR Topic=(payment* environment* service) OR (Topic= environment* service NOT Topic= payment* environment* service Refined by: Topic=(ecosystem))	9857 (9169/1038/3700) [§]
ES_agri	ES_all refined by: Topic=(agricultur*)	2072
multip_ES_all	ES_all refined by: Topic=(bundle* OR multiple* service* OR trade*off*)	1148
multip_ES_agri	multip_ES_all refined by: Topic=(agricultur*)	274
multif_all	Topic=(multifunctional*) AND Topic=(agricultur* OR landscape* OR land use* OR forest* OR prairie* OR grassland* OR pasture*)	1167
multif_agri	Topic=(multifunctional*) AND Topic=(agricultur*)	673
ES&multif_all	multif_all AND ES_all	161
ES&multif_agri	ES&multif_all refined by: Topic=(agricultur*)	87

[§] Results of three subsearches, respectively.

The “ES_all” category includes publications on ecosystem services and alternative names such as environmental services. The “environmental service” search term returned thousands of publications related to environmental services in hospitals, buildings, communities, and various other settings, so we refined it by searching for two types of publications: one involving “payments for environmental services” and another not involving “payments for environmental service” but involving “ecosystem”. Because “ecology service” is usually used as a general term instead of a strict indicator of a research approach, and a search for this term returns thousands of nonrelated publications, we excluded it from our queries at the cost of a minimal underestimation.

The “multip_ES_all” category includes all the publications addressing multiple ES (e.g. bundle of ES, trade-offs).

The “multif_all” category includes publications using the ideology of MFA in research on multifunctional agriculture, forest, prairie, grassland, pasture, land use, and landscape.

The “ES&multif_all” category includes the intersection of publications on MFA and those on ES in the general sense.

Finally, we refined the four previous categories to find their subsets involving agricultural problems, namely, the “multif_agri” category, the “ES_agri” category, the “multip_ES_agri” category, and the “ES&multif_agri” category, respectively.

Quantity of publications

Table 1 presents the search methods and results of the above eight categories of publications.

The total publications on ES were more than the total publications on MFA (9857 vs. 1167). There was less contrast between ES and MFA when the queries were restricted to publications concerning agriculture (2072 vs. 673). A smaller proportion of the ES publications involved agricultural research compared with the MFA publications (21.0% vs. 57.7%). The number of publications involving *multiple* ES was almost the same as that of MFA (1148 vs.1167); fewer publications addressed *multiple* ES than MFA when the queries were restricted to publications concerning agriculture (274 vs. 673).

Results suggest that the number of ES publications was larger than that of MFA publications because ES engaged in a broad range of subjects other than agriculture, and research could focus on a single ES. For the problem of multiple functions or services from agriculture, the concept of MFA was applied as much as that of ES. Some research used both concepts, but was a small proportion of the total (1.6% of the ES publications and 13.8% of the MFA publications).

Trends over time

Fig. 1 presents the trends of the above eight categories of publications from 1975 to November 15, 2013. Publication in all eight categories showed an increasing global trend. The MFA and ES emerged in the 1980s, quietly incubated in the 1990s, and flourished in 2000s. MFA publications steadily increased from 2001, whereas ES publications increased explosively right after the end of the United Nation’s Millennium Ecosystem Assessment program in 2005. Agricultural research has always made up a greater proportion of the MFA publications than of the ES publications. Publications on multiple ES appeared in 1992, and publication using both MFA and ES appeared in 1999. For publications addressing multiple functions or services involving agriculture, MFA publications started increasing earlier and grew faster than those of ES, but the latter show much stronger growth in recent years.

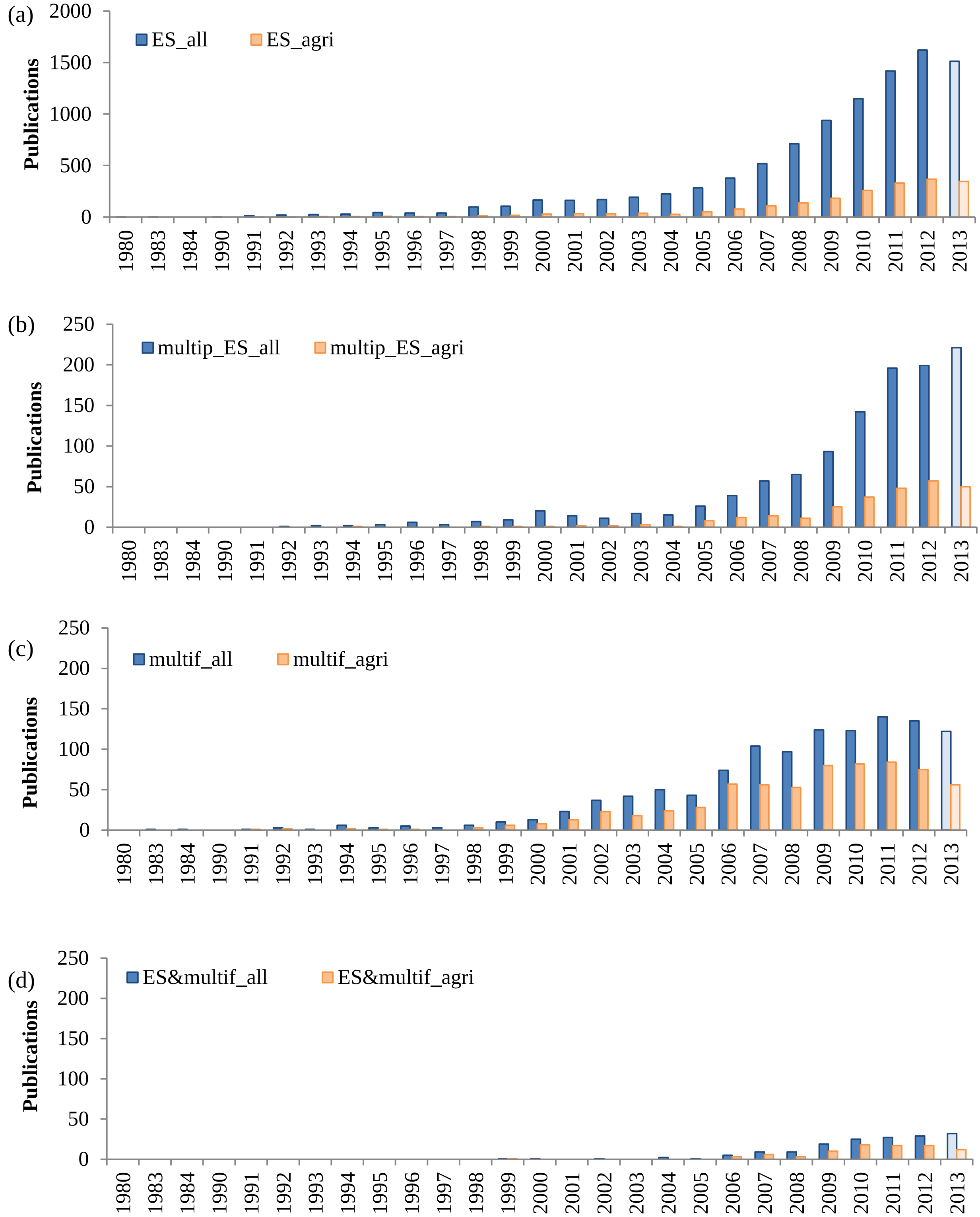

Fig. 1. Multifunctional agriculture (MFA) and ecosystem services (ES) research trends. Search on the Web of Science from 1975 to 2013-11-15. a. “ES_all”: all the publications on ES; “ES_agri” publications on ES involving agriculture. b. “multip_ES_all”: publications on the problem of multiple ES; “multip_ES_agri”: publications on the problem of multiple ES involving agriculture. c. “multif_all”: total publications using the ideology of MFA; “multif_agri”: publications on multifunctional agriculture. d. “ES&multif_all”: intersection of publications on MFA and those on ES; “ES&multif_agri”: intersection of publications on MFA and those on ES involving agriculture.

Appendix 2. Questionnaire for local authority about abandoned farmlands

Questionnaire élus PNR Haute Vallée de Chevreuse

I Localisation

1. Depuis combien de temps êtes-vous maire/élu de la commune ?
2. Quelles sont les grandes orientations de votre municipalité en termes de développement durable/environnement/entretien des espaces verts etc. ?
   Relance : Avez-vous commencez à élaborer un Agenda 21 ? Comment ça marche la gestion différencié des ordures dans la commune ? Il y a un chargé d'environnement ?
3. Quels rapports entretenez-vous avec le PNR, quels sont les contraintes / atouts de l'appartenance de votre municipalité à cette structure ?

II Perception

4. Savez-vous ce qu'est une friche et une jachère ? Y a-t-il des différences entre les deux ?
   Si le sujet n'arrive pas à répondre donner les définitions suivantes :
   - **La friche correspond à un état transitoire, celui d'une terre anciennement cultivée ou pâturée, puis abandonnée qui évolue naturellement vers la forêt.**
   - **La jachère est l'état d'une terre non cultivée qu'on laisse reposer temporairement en ne lui faisant pas porter de récolte afin qu'elle produise ensuite abondamment afin de reconstituer la fertilité du sol.**

5. Quelle image donc avez-vous des friches et des jachères ?
   Relances : insertion dans le paysage, rôle dans l'agriculture, rôle social.
6. En partant de cette liste choisissez 5 termes qui correspondent le mieux à l'image que vous vus faites des friches. **(Donner au sujet la liste – Voir Tableau 1)**
   → Faire expliquer au sujet ces choix.
7. Selon vous cette perception représente elle aussi celle de vos administrés ?
8. Pouvez-vous localiser sur une carte les friches et jachères dans votre commune ?
   Présenter une carte
9. Les friches présentes sur votre territoire sont-elles liées à une opération de remembrement ?
10. Dans la réalisation de votre PLU/POS savez-vous dans quelle zonage sont située ces espaces ?
    Relance : nombres, localisations, propriétaires, Zone A, U etc.

Friche et aménagement territorial

11. Quelle est votre stratégie territoriale vis-à-vis de ces espaces ?

Relance : A quels enjeux pensez-vous qu'ils correspondent ? Avez-vous des volontés d'urbanisation sur ces espaces ?

12. Pensez-vous que ces espaces ont un rôle, une fonction territoriale en tant que tels ?

Relance : fonction environnementale, fonction sociale, opportunité économique.

13. Les friches sont-elles intégrées aux futurs projets ? Quelles affectations ont-elles ?
14. Avez-vous mis en place une concertation (agriculteurs, habitants, associations) par rapport aux différents projets vis-à-vis des friches potentiellement présentes sur les projets ?

III Services éco systémiques ou environnementaux

Arrivez a ce point de l'entretien, après avoir définis ces espaces, l'objectif sera de vérifier les possibles services que ce derniers peuvent apporter au écosystème local. Pour se faire Il nous semble important de définir au préalable la notion d'écosystème :

Système formé par un environnement (biotope) et par l'ensemble des espèces (faune et flore) qui y vivent, s'y nourrissent et s'y reproduisent et qui Interagissent entre eux.

En partant de cette définition quels sont les services que ces espaces peuvent apporter :
En partant de cette liste choisissez 5 services le plus essentiels selon vous (voir Tableau 2)
Apres qu'il a choisi, lui demander de les classer du plus important au moins important.

→ Faire expliquer au sujet ces choix.

Faire attention dans le cas de Saint-Rémy à poser des questions spécifiques sur la friche d'étude

15. Est-il possible de les aménager afin de développer les services rendus par les friches ?

Relance : Gestion écologique des friches (GEF PNR Vosges du Nord 1990) avec introduction d'un élevage de Highlands adapté au milieu naturel présent sur la friche…

→A l'issue de cet entretien, pensez-vous que les friches agricoles devraient être :

-A : Laissées en l'état
-B : Gérées écologiquement
-C : Remises en culture
-D : Urbanisées
-E : Des espaces de loisirs

Pour terminer l'entretien nous vous proposons une liste de mots pouvant évoquer des sentiments sur la friche, nous vous demandons d'en choisir 5 qui pour sont les plus symboliques et les plus pertinents d'après vous (voir tableau 3).
→ Faire expliquer au sujet ces choix.

Appendix 3. Questionnaire for residents about abandoned farmlands

Questionnaire Habitants PNR de la Haute Vallée de Chevreuse

I Localisation

1. Pourquoi habitez-vous en milieu rural ? Comment y êtes-vous arrivé ? Avez-vous l'intention d'y rester ?
2. Comment ressentez-vous la proximité avec les espaces agricoles et forestiers ?

II Perception

3. Savez-vous ce qu'est un PNR ? Avez-vous conscience d'habiter dans un PNR ?
   Relance : Pourquoi ? Avez-vous le sentiment que cela crée des différences (in ou out du PNR) ? Des contraintes ?
4. Savez-vous ce qu'est une friche et une jachère ? Y a-t-il des différences entre les deux ?
   Si le sujet n'arrive pas à répondre donner les définitions suivantes :
   - **La friche correspond à un état transitoire, celui d'une terre anciennement cultivée ou pâturée, puis abandonnée qui évolue naturellement vers la forêt.**
   - **La jachère est l'état d'une terre non cultivée qu'on laisse reposer temporairement en ne lui faisant pas porter de récolte afin qu'elle produise ensuite abondamment afin de reconstituer la fertilité du sol.**

5. Voyez-vous des différences entre friche agricole (espace non construit et non exploité) et jachère ? Comment percevez-vous ces deux espaces ?
6. Quelle image donc avez-vous des friches et des jachères ?
   Relances : insertion dans le paysage, rôle dans l'agriculture, rôle social.
7. En partant de cette liste choisissez 5 termes qui correspondent le mieux à l'image que vous vus faites des friches. **(Donner au sujet la liste – Voir Tableau 1)**
   → Faire expliquer au sujet ces choix.
8. Avez-vous l'habitude d'en voir ? Passez-vous régulièrement devant ?
9. Pouvez-vous localiser sur une carte les friches et jachères dans votre commune ?
   Présenter une carte

Friche et aménagement territorial

10. Que pensez-vous des espaces non exploités et non bâtis ? Quels devraient être leurs rôles ?

11. Dans l'hypothèse où la mairie choisit de construire un lotissement sur une friche agricole, quel est votre avis a priori ?

III Services éco systémiques

Arrivez à ce point de l'entretien, après avoir défini ces espaces, l'objectif sera de vérifier les possibles services que ces derniers peuvent apporter à l'écosystème local. Pour ce faire, il nous semble important de définir au préalable la notion d'écosystème :

Système formé par un environnement (biotope) et par l'ensemble des espèces (faune et flore) qui y vivent, s'y nourrissent et s'y reproduisent et qui Interagissent entre eux.

En partant de cette définition quels sont les services que ces espaces peuvent apporter :
En partant de cette liste choisissez 5 services le plus essentiels selon vous (voir Tableau 2)
Apres qu'il a choisi, lui demander de les classer du plus important au moins important.
→ Faire expliquer au sujet ces choix.

12. A la lumière de cet éclairage, pensez-vous que les friches ont un intérêt ?

13. Pensez-vous que la puissance publique devrait intervenir sur ces espaces d'une manière ou d'une autre ?
    <u>Relance : urbanisation, préservation, aménagement de loisir, remise en culture</u>...

→A l'issue de cet entretien, pensez-vous que les friches agricoles devraient être :

-A : Laissées en l'état
-B : Gérées écologiquement
-C : Remises en culture
-D : Urbanisées
-E : Des espaces de loisirs

Pour terminer l'entretien nous vous proposons une liste de mots pouvant évoquer des sentiments sur la friche, nous vous demandons d'en choisir 5 qui pour sont les plus symboliques et les plus pertinents d'après vous (voir tableau 3).
→ Faire expliquer au sujet ces choix.

Appendix 4. Questionnaire for farmers about abandoned farmlands

Questionnaire agriculteur PNR Haute Vallée de Chevreuse

I Localisation

1. Depuis combien de temps êtes-vous agriculteur ? Quel type d'agriculture pratiquez-vous ?

2. Avez-vous déjà eu des opérations de remembrement au sein de votre commune ? Ont-elles touchés votre exploitation ?

3. Est-ce que le fait d'être exploitant dans le PNR influence-t-il votre mode de culture ?

4. Savez-vous combien de friches et de jachères il y a dans votre commune et où elles sont localisées ?
   Présenter une carte
5. Avez-vous des surfaces non exploitées ?

Relance : Si oui, quelle est leur utilité (économique, écologique, de loisir…), percevez vous les compensations de la PAC pour le gel des terres ?
Si non, envisagez-vous de faire des jachères ou d'abandonner la production sur une partie de vos terres ? Envisagez-vous de demander la compensation gel des terres de la PAC ?

II Perception

6. Quelle image donc avez-vous des friches et des jachères ?

Relances : insertion dans le paysage, rôle dans l'agriculture, rôle social.

7. En partant de cette liste choisissez 5 termes qui correspondent le mieux à l'image que vous vus faites des friches. **(Donner au sujet la liste – Voir Tableau 1)**
   → Faire expliquer au sujet ces choix.
8. Comment pensez-vous que les gens considèrent les espaces agricoles non exploités ?

Relance : différence de perception entre un espace cultivé et un espace abandonné, conflits éventuels au sein de la commune…

Friche et aménagement territorial

9. Si la mairie choisit de construire un lotissement sur une friche agricole, qu'en pensez-vous ?

Relance : si la réponse est négative, alors quelle solution trouveriez-vous adapté (espace de loisir, laissé en l'état, reprise de la culture…)

10. Possédez-vous des parcelles en friches ? Si oui : Savez-vous si certaines de vos parcelles en friche sont concernées par les nouveaux projets d'aménagement ?
11. Pouvez-vous nous parler des Mesures Agro Environnementale ? Au sein de votre agriculture adhérez-vous à ses mesures ? Si oui pourquoi ? Si non pourquoi ?

12. Quelle image avez-vous du PNR ?

Relance : atouts et contraintes

III Services écosystémiques

Arrivez à ce point de l'entretien, après avoir défini ces espaces, l'objectif sera de vérifier les possibles services que ce derniers peuvent apporter au écosystème local. Pour ce faire, il nous semble important de définir au préalable la notion d'écosystème :

Système formé par un environnement (biotope) et par l'ensemble des espèces (faune et flore) qui y vivent, s'y nourrissent et s'y reproduisent et qui Interagissent entre eux.

En partant de cette définition quels sont les services que ces espaces peuvent apporter :
En partant de cette liste choisissez 5 services le plus essentiels selon vous (voir Tableau 2)
Apres qu'il a choisi, lui demander de les classer du plus important au moins important.
→ Faire expliquer au sujet ces choix.

13. Quels services les friches agricoles/jachères vous rendent-elles en tant qu'agriculteur ?
Relance : fertilisation des sols, diminution des couts de production, lieux de chasse…

14. Comment définiriez-vous les services rendus à l'homme et à l'agriculture par les friches ?
Relance : services positifs/négatifs

→A l'issue de cet entretien, pensez-vous que les friches agricoles devraient être :

-A : Laissées en l'état
-B : Gérées écologiquement
-C : Remises en culture
-D : Urbanisées
-E : Des espaces de loisirs

Pour terminer l'entretien nous vous proposons une liste de mots pouvant évoquer des sentiments sur la friche, nous vous demandons d'en choisir 5 qui pour sont les plus symboliques et les plus pertinents d'après vous (voir tableau 3).
→ Faire expliquer au sujet ces choix.

Appendix 5. Questionnaire for environmental associations about abandoned farmlands

Questionnaire Association Environnement Chevreuse

I Localisation

1. Quel est votre périmètre d'action ?

2. Pouvez-vous nous dessiner un rapide historique de l'association et les raisons de l'implantation en Chevreuse ?

3. Quelles sont vos grandes thématiques de travail en lien avec le territoire du PNR ?

Relance : agriculture, forêt, lutte contre l'étalement urbain…

4. Pouvez-vous localiser sur une carte les/des friches agricoles sur le territoire du PNR ?
   Présenter une carte

II Perception

5. Savez-vous ce qu'est une friche et une jachère ? Y a-t-il des différences entre les deux ?

   Si le sujet n'arrive pas à répondre donner les définitions suivantes :
   - **La friche correspond à un état transitoire, celui d'une terre anciennement cultivée ou pâturée, puis abandonnée qui évolue naturellement vers la forêt.**
   - **La jachère est l'état d'une terre non cultivée qu'on laisse reposer temporairement en ne lui faisant pas porter de récolte afin qu'elle produise ensuite abondamment afin de reconstituer la fertilité du sol.**

6. Voyez-vous des différences entre friche agricole (espace non construit et non exploité) et jachère ? Comment percevez-vous ces deux espaces ?

7. Quelle image donc avez-vous des friches et des jachères ?
   Relances : insertion dans le paysage, rôle dans l'agriculture, rôle social.

8. En partant de cette liste choisissez 5 termes qui correspondent le mieux à l'image que vous vus faites des friches. (Donner au sujet la liste – Voir Tableau 1)

9. Quel est le positionnement de l'association sur les friches agricole et les jachères et mène-t-elle des actions sur ces espaces ?

10. Quels rapports entretenez-vous avec les agriculteurs du parc ?

Relance : échange d'information, travail partenarial, conflit…

III Services éco-systémiques

Arrivez a ce point de l'entretien, après avoir définis ces espaces, l'objectif sera de vérifier les possibles services que ce derniers peuvent apporter au écosystème local. Pour se faire Il nous semble important de définir au préalable la notion d'écosystème :

Système formé par un environnement (biotope) et par l'ensemble des espèces (faune et flore) qui y vivent, s'y nourrissent et s'y reproduisent et qui Interagissent entre eux.

En partant de cette définition quels sont les services que ces espaces peuvent apporter :
En partant de cette liste choisissez 5 services le plus essentiels selon vous (voir Tableau 2)
Apres qu'il a choisi, lui demander de les classer du plus important au moins important.

11. Si une commune choisit d'établir un lotissement sur une friche agricole, quelle serait la position de votre organisation ?
12.
13. Pensez-vous que la puissance publique ou des associations telles que la votre devrait intervenir sur ces espaces d'une manière ou d'une autre ?

Relance : urbanisation, préservation, aménagement de loisir, remise en culture…

➔A l'issue de cet entretien, pensez vous que les friches agricoles devraient être :

-A : Laissées en l'état
-B : Gérées écologiquement
-C : Remises en culture
-D : Urbanisées
-E : Des espaces de loisirs

Pour terminer l'entretien nous vous proposons une liste de mots pouvant évoquer des sentiments sur la friche, nous vous demandons d'en choisir 5 qui pour sont les plus symboliques et les plus pertinents d'après vous (voir tableau 3).
➔ Faire expliquer au sujet ces choix.

Appendix 6. A table to be filled by the interviewee about his/her definition of abandoned farmlands

Tableau 1

J'associe la friche à :

Un espace à protéger	
L'Abandon	
Une réserve de Biodiversité	
Une opportunité foncière/ politique	
Un espace de refuge pour flore et faune	
Une zone de non-droit (décharge, campement, etc.)	
Un espace de loisirs (balade, chasse etc.)	
Un espace gaspillé	
Une zone tampon face à l'urbanisation/et aux risques naturels	
Une obstruction du paysage	

Avez-vous d'autres suggestions ?

Appendix 7. A table to be filled by the interviewee about his/her perception of the potential utilities of abandoned farmlands

Tableau 2

La Friche comme espace :

A. Utilisable par la prévention des risques naturels	
B. Favorable à la pollinisation	
C. Utilisable pour la faune comme lieux d'habitat	
D. Utilisable pour une urbanisation future	
E. Potentiel de remise en culture par les agriculteurs	
F. Régulation des cycles naturels (eau, carbone, fonction d'autoépuration etc.)	
G. Utilisable à des fins de loisirs/éducatifs/récréatifs (chasse, scouts, sortis d'école etc.)	
H. Favorable au développement de certaines espèces végétales	
I. Utilisable par des particuliers (équitation, pâturage etc.)	

Classez du plus important au moins important :

1.
2.
3.
4.
5.

Avez-vous d'autres suggestions ?

Appendix 8. A table to be filled by the interviewee about his/her perception of the potential utilities of abandoned farmlands

Tableau 3

La friche évoque un espace plutôt :

Agréable	
Sauvage	
Plaisant	
Risqué	
Naturel	
Sinistre	
Accueillant	
Délaissé	
De découverte	
Négligé	

Avez-vous d'autres suggestions ?

Appendix 9. Information of the actors interviewed

Code of actor	Municipality	Sex	Age	Professional
E1	Cernay-la-Ville	M	55-65	Mayor
H11	Cernay-la-Ville	F	25-30	Secretary Garage
H12	Cernay-la-Ville	M	45-50	Estate Agent
H13	Cernay-la-Ville	M	65	Insurance Agent
A1	Cernay-la-Ville	M	60-70	Farmer
E2	Le Perray	F	35-40	Town planning Agent
H21	Le Perray	M	45-50	Estate Agency Director
H22	Le Perray	M	25-30	Municipal Housing Service Agent
A2	Le Perray	M	60	Conventional Farmer
E3	Auffargis	M	65-70	Town planning Agent
H31	Auffargis	F	40-45	Mayor ‘s Secretary
H32	Auffargis	F	45-50	Mayor’s Secretary
H33	Auffargis	M	65	Supervisor
A3	Auffargis	M	25	Organic Farmer
E4	La Celle-les-Bordes	M	65_70	Mayor
H41	La Celle-les-Bordes	F	45-50	Librarian
H42	La Celle-les-Bordes	M	65-70	Supervisor
A4	La Celle-les-Bordes	F	40-45	Organic Farmer
E5	Saint-Rémy-L'Honoré	F	60-65	Town Councillor
H51	Saint-Rémy-L'Honoré	F	50-55	Librarian
H52	Saint-Rémy-L'Honoré	M	30-35	Engineer in inforamtics
H53	Saint-Rémy-L'Honoré	F	45	Director of a community centre
A5	Saint-Rémy-L'Honoré	M	35-40	Organic Farmer
E6	Saint-Rémy-lès-Chevreuse	M	65	Town Councellor in charge of Environment
H61	Saint-Rémy-lès-Chevreuse	M	40	Youth animating person
H62	Saint-Rémy-lès-Chevreuse	F	45	Estate Agency Director
A6	Saint-Rémy-lès-Chevreuse	M	65	Conventional Farmer
E8	Triel-sur-Seine	M	30-35	Town planning Agent
H81	Triel-sur-Seine	F	55-60	Supervisor
H82	Triel-sur-Seine	F	25-30	Old people’s house Agent
H83	Triel-sur-Seine	M	40-50	Supervisor
H84	Triel-sur-Seine	F	45-50	Municipal Agent Vernouillet
H85	Triel-sur-Seine	M	75-80	Historian
H86	Triel-sur-Seine	F	25-30	Driving School Secretary
E9	Carrière-sous-Poissy	M	30-35	Town planning Agent
H91	Carrière-sous-Poissy	M	70-75	Retired
H92	Carrière-sous-Poissy	M	40-45	Personal care Agent
H93	Carrière-sous-Poissy	F	40-45	Administrative agent
H94	Carrière-sous-Poissy	F	40-45	Aesthetician
H95	Carrière-sous-Poissy	M	45-50	Hair Dresser
H96	Carrière-sous-Poissy	F	55-60	Hair Dresser
E7	Vernouillet	F	40-45	Town planning Agent
H71	Vernouillet	M	40-45	Estate Agent
H72	Vernouillet	F	40-45	Socila animating person CCSA
H73	Vernouillet	F	45-50	Associations’ House secretary
H74	Vernouillet	F	30-35	Flower Seller
H75	Vernouillet	F	55-60	Music School Director
H76	Vernouillet	F	35-40	Hair Dresser
As7	Vernouillet	M	55-60	Director of the territorial association ADAPAVE

Appendix 10. Binary table about the perceptions on ecosystem services/disservices and reuse of abandoned farmlands

Perceptions on ecosystem services (ES), disservices (DS) and reuse of abandoned farmlands

	ES1	ES2	ES3	ES4	ES5	ES6	ES7	ES8	DS1	DS2	Uagr	Uurb	Ueco	Urec	Area
A1	1	1	1	1	0	0	1	0	1	0	1	0	0	0	1
A2	0	0	0	0	0	0	1	0	0	0	0	0	1	0	1
A3	0	1	1	0	0	1	1	0	1	0	1	0	0	1	1
A4	1	1	0	1	1	1	1	0	0	0	0	0	0	0	1
A5	1	1	1	0	0	0	1	0	0	0	1	0	0	0	1
A6	0	1	1	0	1	0	0	0	1	1	1	0	0	0	1
As7	1	1	0	1	1	0	1	1	1	0	1	0	1	0	2
E1	1	1	0	1	1	1	0	0	1	0	0	0	0	1	1
E2	1	1	1	1	0	0	0	1	1	0	1	0	0	0	1
E3	1	1	1	1	0	0	0	0	0	0	1	0	1	0	1
E4	1	1	1	1	0	0	1	0	1	1	0	0	0	1	1
E5	0	1	0	0	1	1	1	1	0	0	1	0	1	1	1
E6	0	1	1	1	1	0	1	0	1	0	1	0	0	0	1
E7	1	1	1	0	1	0	0	1	1	0	1	0	1	0	2
E8	0	1	0	1	0	0	0	0	0	1	1	1	0	0	2
E9	0	1	0	0	0	1	1	0	1	0	1	0	1	1	2
H11	0	1	0	0	1	1	1	1	0	0	1	0	0	1	1
H12	1	1	1	1	0	0	0	0	1	0	1	1	1	0	1
H13	0	1	0	1	0	0	0	0	1	1	1	0	0	1	1
H21	0	1	0	0	0	0	0	0	0	0	1	1	0	0	1
H22	0	1	0	0	1	1	0	0	0	0	0	1	0	1	1
H31	0	1	1	0	1	0	0	0	1	0	1	0	0	1	1
H32	0	1	1	1	0	0	0	0	1	0	0	0	0	1	1
H33	1	1	1	0	0	0	0	0	0	0	1	0	1	1	1
H41	0	1	0	1	1	0	0	1	1	0	1	0	0	0	1
H42	0	1	1	0	1	1	0	0	0	0	0	0	1	1	1
H51	1	1	1	1	1	0	1	0	0	1	0	0	0	0	1
H52	0	1	1	0	1	0	0	0	1	1	1	1	0	1	1
H53	1	1	1	1	0	0	1	0	1	0	0	0	0	0	1
H61	0	1	1	0	1	0	1	1	1	0	1	0	1	0	1
H62	1	1	1	1	1	0	0	0	0	1	0	0	0	0	1
H71	1	1	1	0	1	1	1	1	0	0	1	0	1	0	2
H72	1	1	1	0	1	0	1	0	0	1	1	0	0	0	2
H73	1	1	1	1	1	1	1	0	0	0	1	0	0	0	2
H74	0	1	1	0	0	1	1	1	1	0	0	0	1	1	2

H75	0	1	1	0	0	0	1	0	1	1	0	0	1	1	2
H76	0	1	0	0	1	0	1	0	1	0	1	0	1	1	2
H81	1	1	1	1	0	0	1	0	1	0	1	0	0	0	2
H82	0	1	1	0	0	1	0	1	0	0	0	0	1	1	2
H83	0	1	1	0	1	0	0	0	1	0	0	1	0	0	2
H84	1	1	1	1	0	1	1	1	0	0	1	0	1	0	2
H85	0	1	0	1	0	1	1	1	0	1	1	0	1	1	2
H86	1	1	1	0	0	1	1	1	1	0	0	0	0	1	2
H91	0	1	1	1	0	0	1	0	1	0	0	0	0	1	2
H92	1	1	0	0	1	1	1	0	0	0	0	0	0	1	2
H93	0	1	0	0	0	0	0	0	1	1	1	1	0	1	2
H94	0	1	1	0	0	0	1	0	1	0	1	1	1	0	2
H95	1	1	0	1	1	0	1	1	1	0	0	0	1	1	2
H96	0	1	1	0	0	0	1	0	1	1	1	0	0	1	2

Notes: ES1: biodiversity; ES2: wildlife habitats; ES3: pollination; ES4: water or climate regulating; ES5: resistence to natural risk; ES6: entertainment; ES7: Education; ES8: esthetic service; DS1: illegal waste dumping or camping; DS2: obstruction of landscape; Uarg: used as agricultural lands; Uurb: used for urbanization; Ueco: protected for ecological interest; Urec: used for recreation. H: habitants; A: farmers; E: local authorities; As: environmental associations. Municipalities: 1. Cernay-la-Ville, 2. Le Perray, 3. Auffargis, 4. La Celle-les-Bordes, 5. Saint-Rémy-L'Honoré, 6. Saint-Rémy-lès-Chevreuse, 7. Vernouillet, 8. Triel-sur-Seine, 9. Carrière-sous-Poissy. Area1: PNR Chevreuse; Area 2: Bench of Seine at Triel.

Appendix 11. Questionnaire farmer about urban waste use

A. Eléments agronomiques

1. SAU ? Parcellaire d’exploitation (dispersé ou concentré), RPG

2. Assolement (variation interannuelle ?), succession de cultures

3. Propriétaire ou locataire ? Installé depuis combien d’années ?

B. Fertilisation organique et minérale

1. Quand et pourquoi commencer à utiliser des PRO urbains ? (matière organique ? substitution engrais ?)

2. Quel type de PRO ? De quelle station ? Quelle qualité ? (copie d’analyses de PRO)

3. Quand est-ce épandu ? Quelle quantité ? Quelle fréquence ? Pourquoi ? (basée sur quelles analyses ?)

4. Sur quelle culture ? Dans quelle succession ?

5. Sur quel type de sol ? *Quelle teneur en carbone organique ?* (copies analyses de sol ?)

6. Quelles contraintes ? (quantités apportées ? calendrier ? météo ? matériel ? sociales ? géographique ?)

7. Quelle fertilisation des parcelles amendées en PRO (cultures amendées et suivantes) ? Apport de fertilisation minérale (NPK) ? Quelle quantité ? Comment tenir compte de l’épandage des PRO ? Changement de pratiques si apport de PRO ?

C. Eléments matériels

1. Quel équipement (épandeur/pulvérisateur) ? Qui épand ? (STEP, autre agriculteur)

2. Stockage à la ferme nécessaire ? Où s’effectue ce stockage (distance de la station) ? Pendant combien de temps ? Comment s’évacuent les eaux ? Problème éventuel ?

3. Transport : Qui prend en charge ? Problème éventuel ?

4. Relations avec les producteurs de PRO ? Quel producteur (STEP, composteur) ? Type de contrat ? Y a-t-il des intermédiaires ?

D. Entourage

1. Risques liés à l’utilisation des déchets urbains ? (pour le sol ? la culture ? la vente des produits agricoles ? autres ?)

2. Quelle valeur d’utilisation des déchets urbains (agronomique, économique, écologique, sociale, etc.) ?

3. Comment lui est-il perçu par son entourage (voisins, commune) ?

4. Conflits éventuels ? Gestion par la commune ? Quelle communication mise en place ?

E. Perspectives

1. Quel avenir pour l’épandage de déchets urbains ? Des mesures à inciter ? (fond de garantie)

2. Epandage, compostage, méthanisation (boues et déchets verts), quels avantage/inconvénients (fertilisation ? analyses ? risques ? prix ? politique ?)

3. Que pensez-vous des autres déchets urbains (ordures résiduaires ménagères) ?

4. Utilisation de PRO agricoles ? Quelle différence avec PRO urbains ?

5. Pourquoi le choix d’épandre des déchets urbains ? (choix économique, fertilisation, service rendu)

Appendix 12. Questionnaire for waste producer of green waste

Guide d'entretien sur le compostage des déchets verts

A. Questions générales

1. Quelles activités ? (compostage de déchets verts ? Co-compostage de boues avec déchets verts ?)

2. Depuis quand ? Pourquoi s'installer ici ?

B. Collecte

1. Périmètre de la collecte? Comment fonctionnent les livraisons ?

2. Y-t-il des différences dans vos relations entre les collectivités publiques et les entreprises du paysage ? Est-ce que les entreprises du paysage ou d'élagage sont prestataires du service public ?

3. Capacité de la station :

- Tonnes des déchets verts collectés ?
- Tonnes des produits ? (composts ? paillages ? biomasses ?)

4. Coûts moyens du traitement (énergie, main d'œuvre, équipements, etc..) ?

5. Partage des coûts : Est-ce que vous payez quelque chose pour les déchets collectés ? Est-ce que vous êtes payés pour ce service ? Est-ce que les collectivités paient pour ça ? Comment calculer ?

6. Est-ce que les collectivités/entreprises du paysage ont encore de la responsabilité du compost ?

C. Traitement

1. Quels sont les processus de traitement (trier, épurer, transformer, broyer, mettre en andains, composter/fermentation, maturation et stockage du compost, etc.) ? Quels produits à l'arrivée ? (compost, paillage, biomasse, co-composts avec les boues ?)

2. Quantités des différentes catégories de produits et différences entre leurs traitements ?

3. Quelles contrôles (température, hygrométrie, prélèvement) ? Quelles analyses sur la qualité des composts ?

4. Quels sont les problèmes courants qui peuvent nuire à la qualité du compost ? (impuretés de plastique ou métaux, ETM, etc.) Quelles en sont les conséquences ?

5. Coûts des traitements pour chaque catégorie (énergie, équipement, main d'œuvre)?

6. Stockage sur le site ? Y-a-t-il des problèmes particuliers ?

7. S'ils font aussi du co-compostage, quelles sont les relations avec les STEPs ?

D. Distribution

1. Comment fonctionnent les chaines de distribution pour les trois types de produits ? Qui et où sont les clients ? Quelle est la proportion d'agriculteurs/de coopératives ? Relations avec les utilisateurs ? Y-t-il des techniciens qui leur donnent des conseils ?

2. Quelles certifications, normalisations, règlementations d'utilisation ? Quels critères principaux (valeurs agronomiques et innocuité, etc. ?)

3. Y a-t-il une organisation fédérative (e.g. syndicat) pour cette filière ? Si oui, est-ce obligatoire d'y participer ?

4. Comment définir le prix ? Quelle proportion des coûts de traitement est payée par les utilisateurs des composts, et quelle proportion payée par les collectivités où sont collectés ces déchets ?

5. Est-ce qu'il y a une bonne acceptation pour ces trois types de produits ? Y a-t-il un produit plus utilisé en agriculture ?

6. Y a-t-il des problèmes après l'utilisation des composts ? Des risques (e.g. métaux lourds) ? Qui est responsable s'il y a un accident ?

7. Y a-t-il de nouvelles attentes de la part des clients pour la qualité des produits ?

E. Perspectives

1. L'utilisation des déchets urbains, quelles valeurs d'utilisation ? (économiques, écologiques, sociales, etc.) Un service à la ville ?

2. Le compostage des déchets verts, quels avantages/ inconvénients? Développement vers méthanisation?

3. Acceptation sociale du compostage des déchets verts (les habitants voisins de la plate-forme/élus locaux/agriculteurs)?

4. « Déchets » ou « produits »?

5. Des mesures à inciter e.g. fond de garantie ?

6. Possibilité de faire co-compostage avec les boues des STEPs ? Intérêts et contraintes ?

7. Possibilité de développer le compostage de déchets de cantines ?

***

Contacts des utilisateurs (agriculteurs, collectivités, etc.) ?

Appendix 13. Résumé long en français de la thèse

1. Introduction

1.1. Les défis de l'agriculture périurbaine

L'agriculture périurbaine concerne l'utilisation agricole de terres autour des villes. Dans la « frange urbain-rural », de nombreuses terres agricoles ont été consacrées à l'urbanisation ou conservées comme réserves foncières pour la construction. Les espaces agricoles sont aussi fortement consommés, dans les zones périurbaines, pour l'extension de réserves naturelles ou de loisirs. On reconnait néanmoins de façon croissante que l'agriculture périurbaine procure de nombreux bénéfices, au-delà même de la production de nourriture. Cependant, l'extension de la migration des urbains vers le périurbain en Amérique du Nord et en Europe, en recherche d'une plus grande proximité avec des espaces ouverts et d'un autre style de vie, a paradoxalement stimulé, à travers un habitat de faible densité, une expansion urbaine croissante et l'éloignement des paysages ruraux toujours plus loin des villes.

De nombreuses recherches ont tenté de proposer des stratégies pour limiter la conversion des terres agricoles en usages urbains. Une première stratégie passe par des zonages restrictifs, comme les Ceintures vertes, les frontières à l'expansion urbaine, les zones d'agriculture protégée et les districts agricoles. Une seconde catégorie passe par des subventions accordées aux agriculteurs, comme des réductions d'impôts fonciers à proximité des villes, ou des formes de compensation pour qu'ils puissent continuer à avoir un usage agricole de ces terres.

Cependant, ces politiques ne sont pas toujours couronnées de succès. Une raison fondamentale en est que les bénéfices multiples de l'agriculture, bénéfices environnementaux, sociaux, de loisirs etc., ne sont pas toujours bien intégrés à côté des bénéfices tirés de la production de nourriture ou de matières premières. Les politiques de zonage sans compensation n'ont pas été en mesure de freiner le grignotage urbain des terres agricoles, en particulier dans les pays en développement, du fait d'occupations illégales de terres ou de l'insuffisance des moyens légaux pour protéger l'agriculture. Lorsqu'elles existent, les compensations financières pour les agriculteurs sont calculées principalement sur les valeurs de production de nourriture ou de matières premières, et sont rarement compétitives par rapport au marché du foncier en péri-urbain. Elles sont parfois efficaces à court terme pour maintenir une occupation agricole, mais rarement à plus long terme.

L'absence de perspectives à une autre échelle, par exemple régionale, fait que les opérations ponctuelles de compensation ne peuvent suffire à prévenir le mitage des terres agricoles, rendant celles qui restent inefficientes à constituer des exploitations agricoles viables. De telles mesures se sont parfois révélées plus efficaces pour protéger des espaces ouverts à vocation naturelle qu'à renforcer le secteur agricole, ce dont rendent compte les conversions massives de terres productives en « hobby farming », terrains de golf, centre équestres, jardins familiaux et autres dans les zones périurbaines. De plus, l'agriculture périurbaine n'est pas la seule forme d'agriculture urbaine destinée à subvenir aux besoins des populations urbaines. Les recherches sur l'agriculture périurbaine doivent considérer les relations entre les différentes parties prenantes pour gérer les multiples bénéfices à tirer du maintien de l'activité agricole.

1.2. Une approche intégrée des Services Ecosystémiques et de la Multifonctionnalité pour la préservation des terres agricoles périurbaines

Les services écosystémiques (SES) sont les bénéfices que les humains retirent directement ou indirectement des fonctions remplies par les écosystèmes. Les recherches sur les SES montrent que les dégradations environnementales dues aux actions humaines résultent de l'ignorance de la valeur de ces SES et du manque d'instruments pour considérer ces valeurs dans les systèmes d'aide à la décision. Les stratégies portant sur les SES ont connu de beaux succès dans la gestion d'écosystèmes naturels au cours des vingt dernières années. Elles peuvent aussi devenir intéressantes pour la recherche agronomique, car les activités agricoles reposent largement sur le fonctionnement d'agro-écosystème. Avec la montée en puissance du concept de SES, la recherche agronomique a progressivement reconnu l'existence de plusieurs SES et impacts concernant l'agriculture, au-delà de la production de nourriture et de matières premières (par exemple, la régulation du climat ou de l'eau, la dépollution), de même qu'elle a reconnu que des SES intermédiaires sont nécessaires au fonctionnement des agroécosystèmes, comme la biodiversité, la fertilité des sols ou le recyclage des nutriments.

L'objectif des recherches en SES dans le domaine agricole est de promouvoir le changement de pratiques culturales afin de combattre l'image de l'activité agricole comme polluante et afin de mieux prendre en compte la notion de biens publics et de services. Des instruments efficaces, comme le paiement pour service écosystémique/service environnemental rendu (PSE) peuvent être utilisés pour la préservation des terres agricoles. Cependant, des agro-écosystèmes sont aussi des systèmes socio-écologiques, qui incluent les résultats d'actions humaines, comme les opérations culturales (traitements, irrigation, fertilisation, travail du sol etc.) ainsi que des aspects sociaux et économiques ou relevant des marchés. Les recherches en SES ont des difficultés à appréhender les différences entre des SES provenant « purement » des écosystèmes et ceux provenant aussi des agriculteurs eux-mêmes. De même, une source fréquente de confusion est de considérer comme « disservices des agro-écosystèmes » des impacts de fait causés par l'homme comme les pollutions aux pesticides, les lessivages de nitrates etc. Pour cette raison, certains chercheurs optent plutôt pour l'étude des services environnementaux. Mais ces services environnementaux sont tout aussi difficiles à intégrer dans les pratiques agricoles, car souvent considérés d'abord comme des contraintes par les agriculteurs. Des politiques visant à la protection de certains SES peuvent de fait compromettre la viabilité des activités des agriculteurs ou d'autres acteurs.

La multifonctionnalité de l'agriculture (MFA) analyse de façon conjointe les fonctions économiques, sociales et environnementales des activités agricoles au-delà de la production de nourriture et de fibres. Les projets existants sur l'agriculture périurbaine axés sur la multifonctionnalité mettent plus souvent en avant les dimensions socio-économiques qu'environnementales. Sont souvent privilégiées les fonctions de production de nourriture, les aménités paysagères et le rôle des agricultures dans la lutte contre les inondations. En France et en Europe, les recherches et les politiques sur la MFA ont prédominé dans les années 1990 au moment des réformes de la politique agricole commune (PAC). Les recherches concernant la MFA ont largement contribué à réorienter les aides de la PAC, axées initialement sur des soutiens monétaires directs à la production, et fonction des surfaces cultivées, vers des aides dirigées vers les agriculteurs et le maintien de leur activité, avec l'objectif de soutenir une occupation agricole de l'espace, reconnue pour sa production mais aussi pour les biens environnementaux qu'elle produit à l'échelle du territoire agricole. Ce concept de MFA a cependant été largement critiqué dans le monde politique comme prônant le protectionnisme, mais aussi pour son manque de précision. La PAC se tourne de fait de nouveau vers des incitations par le marché (PSE) pour la période post-2013.

Les concepts de SES et de MFA ont les mêmes objectifs de reconnaitre les multiples bénéfices et impacts des activités agricoles, au-delà de la production primaire. L'échec actuel de la MFA dans la sphère politique ne signifie pas qu'il faille la remplacer par la notion de SES. Au contraire, ces deux notions sont complémentaires et une approche intégrée des SES et de la MFA est importante pour surmonter les insuffisances de chacun et faire face aux défis en utilisant des paradigmes indépendants. S'agissant des performances de l'agriculture, la notion de MFA permet de mieux prendre en compte la gestion des activités des agriculteurs. La prise en compte multiple et flexible de divers aspects des activités agricoles est à l'avantage de la MFA, qui combine les dimensions économique, sociale et environnementale. La MFA s'avère être une forme de médiation intéressante pour intégrer la logique des SES avec les logiques des bénéfices économiques et sociaux. Ceci peut être bénéfique pour trouver des mesures valides en faveur de la préservation de l'agriculture périurbaine et éviter la conversion de terres agricoles productives en zones de « hobby farming » ou en espaces naturels. A leur tour, les SES peuvent être une base solide pour la définition des fonctions agricoles et ainsi peuvent augmenter la précision de la notion de multifonctionnalité. Fondée sur la notion de cascade de SES, l'approche intégrée peut considérer en tant que tels les rôles des SES et faciliter la gestion de systèmes agraires autorégulés. L'approche intégrée peut aussi permettre de mieux distinguer les contributions des écosystèmes et celles des actions humaines et constituer un cadre pour traiter des relations entre les diverses partie-prenantes. La recherche permettant cette intégration entre SES et MFA est aujourd'hui encore rare.

1.3. Objectifs et structure de la thèse

L'objectif premier de la thèse est d'explorer l'intérêt d'une telle approche intégrée entre SES et MFA pour la préservation des terres agricoles périurbaines. La première partie est ainsi consacrée au développement de ce cadre d'intégration dans cette optique. La seconde et la troisième partie sont des études détaillées de la gestion des terres agricoles en friche d'une part, du recyclage agricole des déchets urbains d'autre part, dans la région Ile-de-France. Ces études détaillées cherchent à démontrer comment cette approche intégrée des SES et de la MFA fonctionne pour traiter de problèmes concrets touchant l'agriculture périurbaine. Des analyses multi scalaires ont été menées dans les deux cas d'étude, avec l'hypothèse que l'expression des SES et de la MFA et leurs prises en compte par les parties prenantes peut varier selon les échelles (de l'échelle nationale et régionale à celle de petits territoires agricoles)..

1.3.1. Développement d'un cadre intégrant MFA et SES pour l'agriculture périurbaine

Deux communautés scientifiques indépendantes se focalisent sur SES ou MFA. Elles montrent chacune un vif intérêt pour l'agriculture durable, mais ont de fait peu d'échanges et d'interactions entre elles. Un premier travail dans cette thèse est dédié à une revue comparée des publications concernant les SES et la MFA dans la littérature de la recherche agronomique. Cette revue compare les tendances des publications, les idéologies et les postures de recherche sous-tendant les approches MFA et SES ; on propose alors un dialogue entre ces deux approches et une tentative d'intégration. Le cadre général conclut notamment à l'intérêt de l'approche MFA pour analyser du point de vue des agriculteurs les multiples services et dis-services écosystémiques, portés par et valorisés par l'agriculture, en tant qu'inputs ou outputs de l'activité agricole sur les exploitations..

Le cadre intégré de SES et MFA a ensuite été utilisé pour le cas d'application spécifique de l'agriculture périurbaine. Les SES sortants de l'activité agricole sont utilisés différemment en fonction des structures économiques et sociales des exploitations, et donc la multifonctionnalité d'une exploitation agricole est variable. Par exemple, le passage, pour les exploitations agricoles, du service d'approvisionnement en produits nourriciers à une fonction alimentaire pour la ville varie en fonction de la nature des circuits commerciaux choisis par les agriculteurs. Lorsque les produits agricoles sont majoritairement destinés au commerce international, l'augmentation du service d'approvisionnement ne se traduit pas nécessairement par une augmentation de la fonction alimentaire pour les urbains proches. Le cadre intégré analyse ces dimensions économiques, sociales et écologiques pour traiter les liens entre services écosystémiques et fonctions agricoles, permettant d'analyser globalement les stratégies déployées par les agriculteurs.

Le cadre est alors appliqué au cas de la Région Ile-de-France, avec l'idée d'éclairer les décisions politiques visant à préserver l'agriculture péri-urbaine. La Région Ile-de-France (région parisienne) a été profondément affectée par l'expansion urbaine et la périurbanisation au cours du siècle dernier, mais conserve encore presque 50% de sa superficie en agriculture. La dégradation de SES causée par l'industrialisation de l'agriculture contraste avec la demande croissante des urbains pour les produits alimentaires locaux, la régulation climatique, et d'autres services encore. L'évolution des instruments politiques, notamment les schémas directeurs régionaux, révèle les intentions des planificateurs de considérer différents services et fonctions offerts par l'agriculture. Le cas de l'Ile-de-France est révélateur pour proposer des mesures à d'autres régions métropolitaines.

Avant de passer aux développements futurs de ce cadre intégré, des recherches ont été menées sur les pertes de terres agricoles, les évolutions structurelles des exploitations et les modèles d'usages du sol en Ile-de-France. L'application du cadre intégré montre qu'au cours du temps, les SES et la MFA ont évolué en lien avec l'évolution des terres agricoles et de leurs usages ; elle montre aussi comment les besoins sociaux ou la consommation de certains services ou fonctions ont guidé ces évolutions d'usage des terres agricoles que sont les céréales en open field, les formes de maraichage, l'arboriculture et les surfaces en herbe.

1.3.2. Etudes détaillées du devenir des friches agricoles et du recyclage des déchets urbains en Ile-de-France

Les friches ou terres abandonnées au sens restreint, sont les terres qui ne sont plus utilisées pour un usage agricole ou pour d'autres activités économiques. L'arrêt complet de la gestion agricole de ces terres les a laissé évoluer par elles même. Ainsi, un couvert végétal se constitue rapidement et évolue de l'herbe à l'embroussaillement puis à la forêt. Devenant des terres « vacantes » au regard de leur usage, ces terres agricoles abandonnées peuvent être converties en terrains à construire, en parcs urbains, en corridors écologiques ou en certaines formes d'agriculture urbaine. Des recherches sur ces processus peuvent aider l'agriculture péri-urbaine à s'adapter aux demandes urbaines de SES et de fonctions remplies, au lieu de se poser toujours en victime de l'urbanisation.

Le recyclage agricole des déchets urbains est particulier car il est fondé sur deux SES, à savoir, le SES de réduction des déchets et le SES de fertilisation des sols. Ainsi, les producteurs de déchets urbains peuvent-ils être à la fois des producteurs de fertilisants agricoles et des acteurs du service de réduction des déchets urbains, et parallèlement les exploitants agricoles peuvent être vus à la fois comme demandeurs de fertilisants organiques et fournisseurs d'un service de réduction des déchets. De multiples facteurs jouent pour influencer la balance entre producteurs de déchets urbains et agriculteurs péri-urbains, comme par exemple les progrès technologiques dans la réduction des teneurs en micro-polluants dans les déchets urbains, les régulations nationales voir européennes concernant ces micro-polluants, ou les perceptions sociales des déchets urbains, entre autres. Au cours du 20ème siècle, les utilisations agricoles des déchets urbains sont passées majoritairement, du service d'élimination des déchets pour la ville à un service de contribution à la fertilisation des terres. Mais il reste néanmoins conflictuel d'aller vers le « paiement de services écosystémiques » aux agriculteurs pour cette élimination de déchets urbains. Les agriculteurs veulent éviter que les terres agricoles soient considérées comme « poubelles des villes ». Le contenu en fertilisants de ces déchets est souvent leur motivation première pour prendre des déchets organiques urbains. Mais ils n'acceptent pas non plus facilement le fait de devoir payer pour ce contenu. Les études sur le recyclage agricole des déchets urbains peuvent éclairer sur le bon usage ou pas des mécanismes de « PSE » pour l'agriculture périurbaine.

L'étude détaillée sur les friches agricoles relève de la gestion d'un type particulier d'usage du sol, tandis que l'étude détaillée sur le recyclage des déchets urbains relève lui de la gestion de services et de fonctions de l'agriculture. Les usages du sol sont communément liés à l'établissement et à la gestion de SES dans la littérature, de même d'ailleurs que dans la PAC réformée, notamment à travers les mesures agri-environnementales (MAE). Les chercheurs parviennent à des matrices reliant des usages du sol à leurs capacités à fournir certains SES et biens associés. L'étude sur l'apparition et le devenir des friches agricoles révèle les interactions mutuelles entre les changements d'usage des sols et l'évolution des SES et des fonctions attribuées au sol. L'étude sur le recyclage agricole des déchets urbains analyse les multiples facteurs influençant la relation offre-demande en déchets urbains. Ces approches peuvent être extrapolées à d'autres usages agricoles que les friches ou à d'autres SES/ fonctions que celles liées aux déchets urbains.

Des analyses multi-échelles sont menées pour ces deux études détaillées, chacune incluant un volet à l'échelle régionale et une investigation plus locale des pratiques et perceptions de différents acteurs : pour ce faire, deux petites zones ont été retenues dans chaque cas. Il apparait que le devenir des friches agricoles nécessite bien une analyse multi-échelle. L'enfrichement qui apparait dans un territoire reflète le changement de structure de ce territoire. Les bénéfices écologiques de l'enfrichement sont vus seulement à l'échelle régionale. L'analyse des friches dans le contexte régional offre des perspectives pour mieux comprendre, prédire et gérer leur devenir à ce niveau. Mais à l'échelle locale, le devenir des friches montre une forte hétérogénéité, non perceptible à l'échelle englobante.Il existe aussi des interactions non négligeables entre ces échelles spatiales. L'enfrichement massif survient dans les zones où de grands projets nationaux urbains sont implantés (villes nouvelles par exemple). Pour comprendre les dynamiques des friches, il est important de comprendre les contradictions et les conflits entre les acteurs locaux et les décideurs à l'échelle régionale, voire nationale.

De même, les flux de déchets urbains utilisés en agriculture sont dans les faits influencés par une grande diversité de facteurs à différents échelles. Des pays différents, y compris au sein de l'Union Européenne, adoptent des seuils très variables d'innocuité des micro-polluants (par exemple en éléments traces métalliques) dans les substrats organiques ou dans les sols, créant ainsi un malaise parmi les autorités régulatrices au niveau mondial. Les hétérogénéités locales se traduisent par des difficultés de gestion entre les échelles. Les législations européennes et françaises sont très strictes et complexes concernant l'apport de boues urbaines aux sols agricoles, mais contrairement aux attentes des décideurs à l'échelle nationale, la société est devenue de plus en plus regardante et méfiante vis-à-vis des épandages agricoles de boues urbaines, surtout dans les zones périurbaines. Des acteurs différents ont aussi des attentes différentes relativement à l'usage agricole des déchets urbains, qu'il s'agisse du jardinier privé, de l'agriculteur, des voisins des fermes péri-urbaines, des associations environnementales ou des agronomes.

Les deux zones étudiées pour l'enfrichement et le devenir des friches sont les boucles de la Seine à Triel-sur-Seine et Carrières-sous-Poissy d'une part, le Parc naturel Régional de Chevreuse d'autre part. Les deux zones utilisées pour l'étude des valorisations agricoles des déchets urbains sont la Plaine de Versailles et le Plateau de Saclay.

2. Développement d'un cadre intégré de MFA et de SES pour l'agriculture périurbaine

2.1. Revue comparée des MFA et SES dans la littérature agronomique

Des statistiques suggèrent que les publications scientifiques sur les SES et la MFA suivent les mêmes tendances. Cette littérature a émergé dans les années 1980, s'est développée au cours des années 1990 et s'est épanouie dans les années 2000. Les publications traitant des SES ou de la MFA relativement à l'agriculture sont plutôt équilibrées en nombre, au contraire des publications plus généralistes. Concernant l'agriculture, les publications portant sur les MFA ont commencé plus tôt et augmenté plus rapidement que celles concernant les SES, mais ces dernières se sont largement rattrapées au cours des dernières années. Les publications sur les SES concernent une très large gamme de sujets autres que l'agriculture, et la recherche se focalise parfois sur un seul SES. Au total, l'augmentation explosive des publications sur les SES peut donner une impression fausse de supériorité sur les tendances de publications relatives à la MFA. Les idées et concepts de MFA et SES ne sont de fait pas nées indépendamment, et leurs principales relations sont synthétisées à la Figure 1.

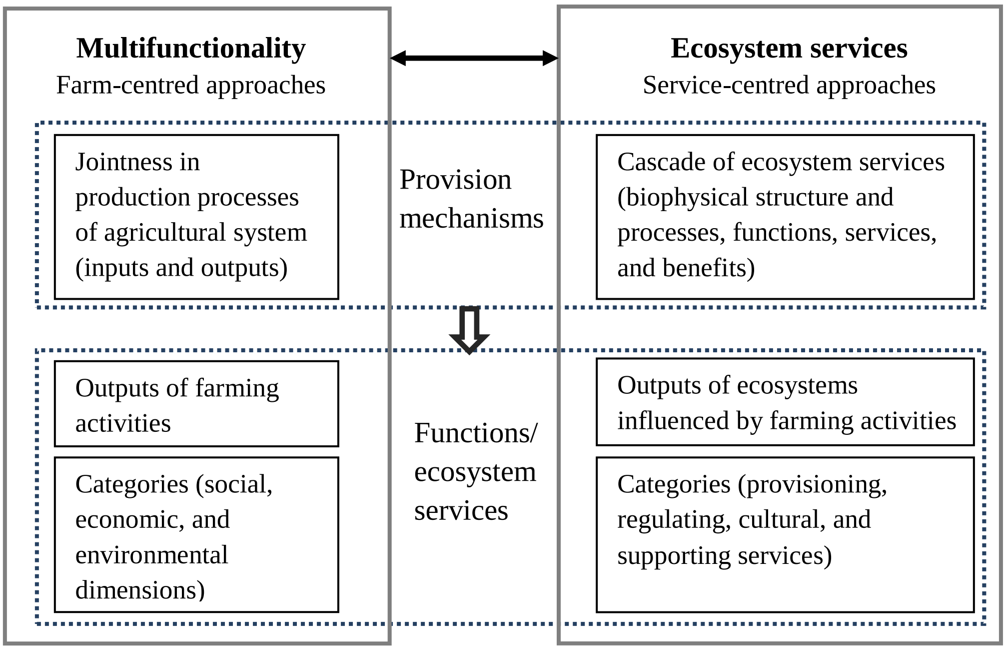

Fig. 1.principales différences entre multifonctionnalité et services écosystémiques dans la recherché agronomiques.

Leurs relations historiques se reflètent dans l'usage partagé mais avec des sens différents, du mot "fonction » (function) dans les deux courants. La MFA interprète le mécanisme de multifonctionnalité en utilisant des modèles intégrés de la production, et identifie trois sources d'intégration (interdépendances techniques, inputs non allouables, inputs allouables à l'échelle de la parcelle). Les ES explique la "chaine de production" des SES au regard de la notion de cascade de services écosystémiques qui comprend plusieurs étapes : structure de l'écosystème et processus en cause, fonction (capacité à rendre un service), service, bénéfice, valeur.

La fourniture de biens et services dans la MFA est vue comme un résultat direct des activités agricoles, alors que dans la mouvance des SES, c'est un résultat du fonctionnement des écosystèmes influencés par ces activités agricoles. Les activités agricoles sont dans ce dernier cas, des facteurs externes qui peuvent modifier, augmenter ou diminuer le niveau de fourniture d'un SES par les agro-écosystèmes.

Ces distinctions de base influencent largement le choix des questions scientifiques et des méthodologies, à travers une préférence pour les approches centrées sur l'exploitation agricole (MFA) versus centrées sur les services (SES). Les recherches en MFA utilisent des modèles de productions combinés à l'échelle de la ferme pour aider au choix de stratégies qui maximisent la production de nourriture et les impacts environnementaux positifs comme la biodiversité, ou qui minimisent les impacts environnementaux négatifs comme les pollutions. Les recherches sur les SES préfèrent des approches centrées sur les services, supportée par le modèle des cascades de SES. L'échelle de recherche ne dépend plus alors de l'exploitation agricole, mais des échelles écologiques et institutionnelles pertinentes pour fournir ces services.

Du fait de leurs approches multidisciplinaires au cours de la dernière décennie, les recherches en MFA et SES partagent cependant quatre objectifs (1) l'identification et la classification de fonctions et de services (2) la quantification, l'évaluation et la cartographie de ces fonctions et services (3) les arbitrages et les synergies entre fonctions et services et (4) le design des multifonctions et la gestion des services écosystémiques. Les recherches associées à chaque concept se développent de manière séparée mais montrent des similarités et des différences importantes. Les revues comparées de la littérature scientifique suggèrent qu'il peut y avoir une forte valeur ajoutée à faire se rencontrer les points de vue et les approches des SES et de la MFA. Cela peut permettre d'ouvrir un dialogue et une communication entre ces communautés MFA et SES, par exemple autour des notions de bouquets de services avec les multifonctions, autour des notions de partage versus économie des terres agricoles.

2.2. Développement d'un cadre général de la MFA et des SES

Nous proposons un cadre conceptuel global d'intégration entre SES et MFA (Figure 2) afin de considérer les multiples services ou dis-services écosystémiques provenant de, ou allant vers, l'agriculture, comme des inputs et outputs dans les modèles de production à l'échelle de l'exploitation proposés par la MFA. Ainsi, en analysant chaque service et interaction sur la base de la cascade des SES, les chercheurs peuvent évaluer les inputs et outputs du système et optimiser les stratégies à l'échelle de la ferme. Par souci de simplification, nous posons que les terres cultivées sont entourées d'habitats semi-naturels comme des zones non cultivées et des bandes enherbées ou fleuries. L'exploitation est la principale unité de décision au sein des territoires agricoles. Les exploitants gèrent aussi des éléments non cultivés comme les bordures de parcelles, les réseaux de haies, si bien que les limites de l'exploitation englobent quelques espaces semi-naturels.

Sur la base de recherches antérieures, nous avons distingué six groupes de services et dis-services du point de vue de leur relation avec l'agriculture (provenant ou s'exerçant sur l'agriculture), des caractéristiques spatiales (sur le site considéré ou en dehors), des catégorie issues de la typologie du Millénium Ecosystem Assessment et des échelles spatiales. Nous utilisons le terme « dis-services » pour désigner des effets négatifs d'activités agricoles tels que le lessivage des nitrates ou les surutilisations de pesticides, et le terme « dis-services écosystémiques » pour désigner les effets négatifs provenant des fonctions des écosystèmes comme les pressions phytosanitaires, la compétition pour l'eau ou la lumière dus aux écosystèmes entourant les exploitations. Les agriculteurs peuvent avoir différentes motivations dans les différents groupes, entrainant l'existence de sous-groupes (par exemple en fonction de l'échelle). Ces six groupes de services/dis-services sont les suivants :

Groupe 1: Services provenant de l'agriculture, orientés vers le consommateur, incluant la fourniture de nourriture, fibres, biocarburants, réduction des déchets, services culturels, récréatifs, éducatifs et esthétiques.

Groupe 2: Services de régulation pour l'agriculture provenant des écosystèmes entourant l'activité agricole, incluant le contrôle biologique des parasites, la pollinisation, l'approvisionnement en eau.

Groupe 3: Services de régulation pour l'agriculture et provenant de l'agriculture, incluant la fertilité des sols, la rétention en eau des sols, la résistance aux perturbations, la régulation climatique.

Groupe 4: Services de soutien des écosystèmes dans les territoires agricoles, incluant le recyclage des nutriments, la conservation de la biodiversité et des habitats naturels.

Groupe 5: Dis-services écosystémiques envers l'agriculture, dont la compétition pour l'eau et la pression parasitaire.

Groupe 6: Dis-services agricoles sur les écosystèmes entourant l'agriculture, incluant le lessivage des éléments nutritifs, l'érosion et les coulées de boues associées, et les excès de pesticides.

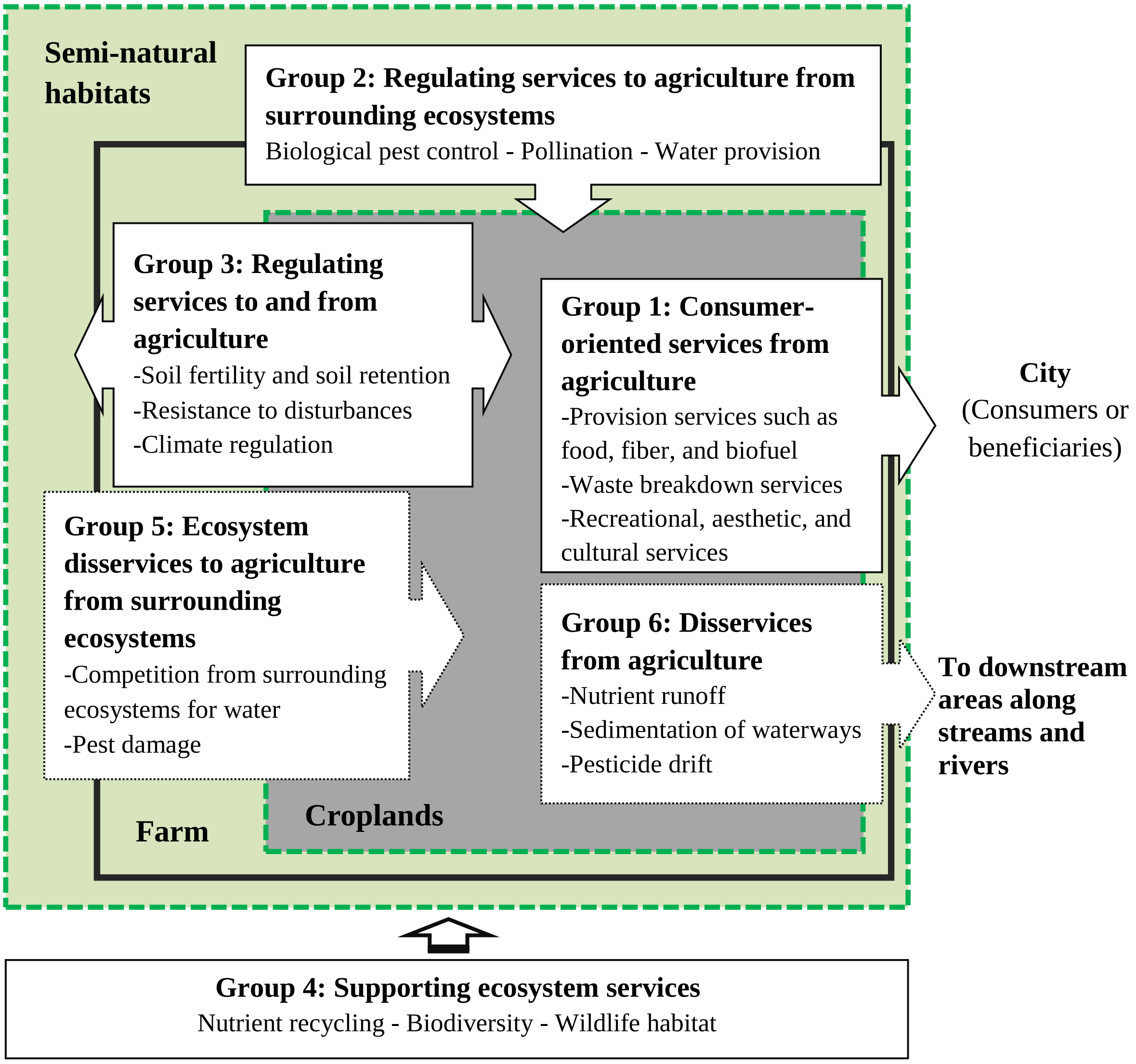

Fig. 2. Le cadre intégré de la multifonctionnalité de l'agriculture et des services écosystémiques.

Ce cadre est alors développé pour être utilisé dans le cas des contextes périurbains (Fig. 3). Le système agraire considéré inclut l'agro-écosystème, le système socio-économique et leurs interactions. Les fonctions agricoles reposent sur les bénéfices tirés des agro-écosystèmes, c'est-à-dire des services écosystémiques. Les flux de SES et de dis-services au sein et en dehors des agro-écosystèmes décrits dans la figure 2, sont illustrés de façon simplifiée par le fait que des services de régulation et de soutien supportent les trois services orientés vers le consommateur. Les agriculteurs, les résidents du périurbain, les urbains, les planificateurs et les politiques sont les principales partie-prenantes du système socio-économique. Celui-ci peut aussi concerner des autorités régionales ou nationales pour la construction par exemple d'infrastructures telles que des aéroports, des autoroutes, des hôpitaux, des prisons etc.

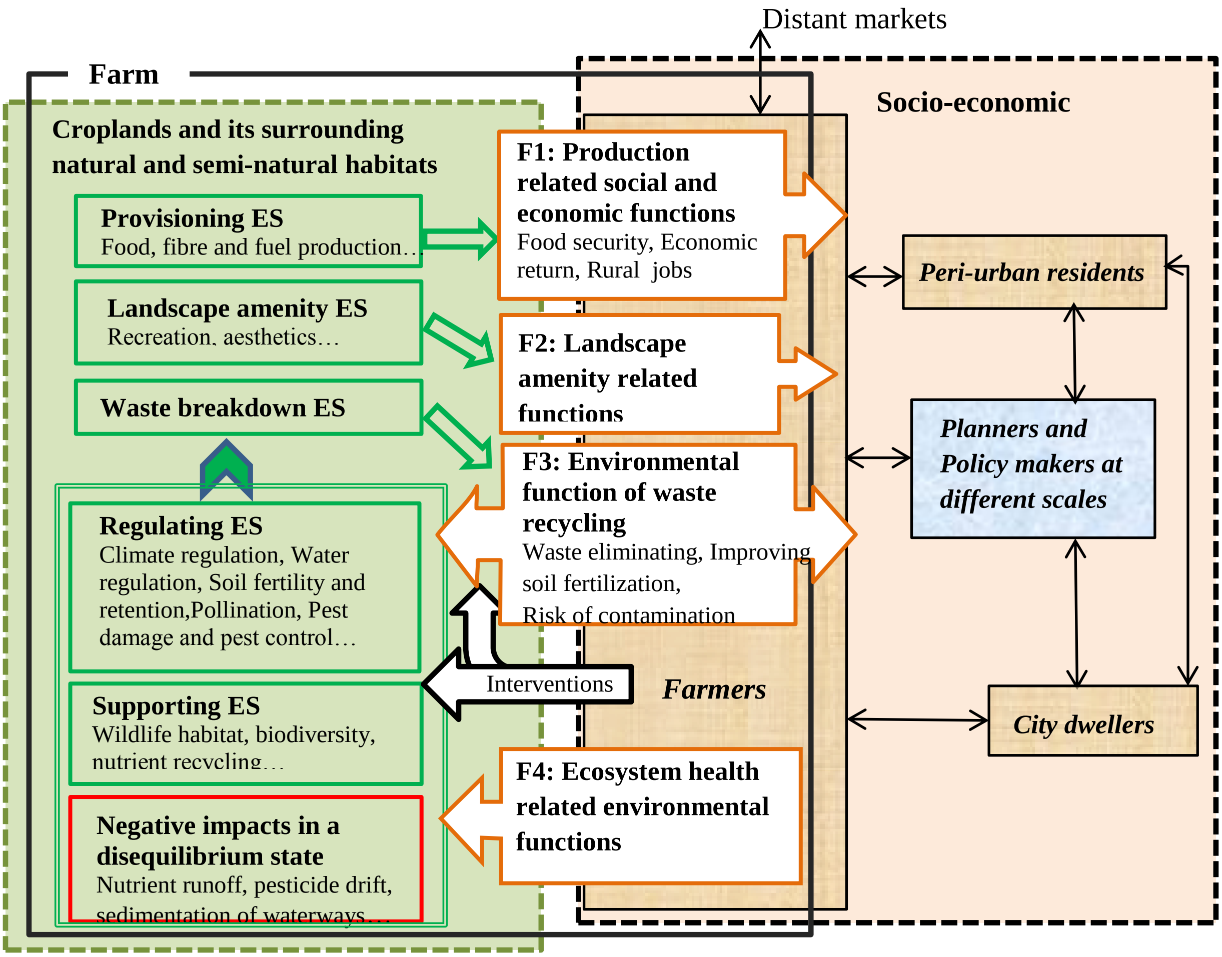

Fig.3. Un cadre intégré de la multifonctionnalité et des séries écosystémiques pour l'agriculture périurbaine. F1, F2, F3 and F4: fonctions remplies par l'agriculture ES : services écosystémiques

Parmi les trois services "orientés consommateur", le service d'approvisionnement en nourriture, fibres, biocarburants, et le service de réduction des déchets, nécessite l'orientation de l'agriculture vers la satisfaction des besoins d'autres partie-prenantes éventuellement éloignées, comme les habitants et consommateurs urbains. Les services récréatifs, esthétiques et culturels peuvent être perçus en partie directement lorsque l'on fréquente les paysages périurbains. Mais les interventions des agriculteurs peuvent modifier plus ou moins les agro-écosystèmes et leurs relations avec les espaces alentour, et ainsi influencer l'offre de ces services. C'est pourquoi nous considérons quatre catégories de fonctions de l’agriculture, en comparant les listes de fonctions trouvées dans la littérature, avec leurs SES sous-jacents.

La première catégorie comprend les fonctions reposant sur les services d’approvisionnement et déterminées par les stratégies des agriculteurs en termes commerciaux, à savoir la sécurité alimentaire, le revenu économique et l’emploi rural. La seconde catégorie comporte les fonctions basées sur les services écosystémiques d’aménités paysagères, perceptibles par ceux qui fréquentent ou travaillent dans les territoires périurbains, comme les services récréatifs, esthétiques et culturels. Les agriculteurs peuvent renforcer ou limiter ces fonctions, par exemple en développant l’agro-tourisme ou en implantant des haies. Les agriculteurs sont d’ailleurs eux même bénéficiaires de ces services et profitent d’un certain style de vie. La troisième catégorie comporte les fonctions de recyclage agricole des déchets urbains, qui est relié à deux services écosystémiques, la réduction des déchets et la fertilisation. Elle peut aussi comporter des risques de contamination des sols et des eaux. Enfin, la quatrième catégorie inclut une diversité de fonctions environnementales permettant le maintien d’agro-écosystèmes en bonne santé et d’habitats naturels les entourant, c’est-à-dire les « services environnementaux » tels que qualifiés par certains chercheurs.

Le cadre facilite l’examen d’importantes questions concernant l’agriculture péri-urbaine. La préservation de cette agriculture ne dépend pas seulement du fait qu’un écosystème en bonne santé délivre « naturellement » des services écosystémiques, mais elle dépend aussi du fonctionnement du système socio-économique et de sa capacité à lutter contre l’expansion urbaine et contre l’abandon des terres agricoles. En particulier, il s’agit de relier l’agriculture périurbaine avec la population urbaine, car dans le cas français et de l’Ile de France en particulier, le nombre d’agriculteurs péri-urbains est très marginal en comparaison avec les autres résidents de ces zones. Quand la production de biens alimentaires par l’agriculture n’est pas connectée à l’approvisionnement des populations urbaines en produits locaux, les acteurs du territoire peuvent difficilement apprécier la production de service d’approvisionnement par l’agriculture. On peut tenir le même raisonnement pour les autres SES et fonctions de l’agriculture péri-urbaine.

2.3. Application dans le cas de la Région Ile-de-France

Les terres agricoles en Ile-de-France ont connu des évolutions drastiques au cours du dernier siècle, sous l’influence conjointe de l’urbanisation, de la modernisation agricole et des politiques agricoles menées après-guerre. Trois grandes périodes peuvent être distinguées :

-Tout d’abord, une période d’expansion urbaine continue avant les années 1960, qui ont vu la décroissance des céréales et oléo-protéagineux, des cultures fourragères et des jachères, au bénéfice des prés et des fruits et légumes. En deuxième lieu, pendant la période de périurbanisation des années 1960 et 1970, la consommation de terres agricoles a été très rapide et a conduit à des nombreux abandons. Les céréales et oléo-protéagineux ont augmenté alors que tous les autres usages agricoles du sol diminuaient. Cette période a marqué la création du modèle intensif et simplifié de l’agriculture d’Ile-de-France d’aujourd’hui. La troisième période a commencé dans les années 1980, avec un certain ralentissement de la construction de villes nouvelles et de périurbanisation, conduisant à une plus lente consommation de terres agricoles. Aujourd’hui, prairies ou arboriculture sont très minoritaires, les terres cultivées étant largement dominées par les céréales et oléo-protéagineux (80-86%), la betterave sucrière (7-8%) et les jachères (4-13%).

Il y a aujourd’hui trois principaux systèmes de production agricole en Ile-de-France : les exploitations de grande culture, composant le paysage d’open-field et composé des céréales, oléo-protéagineux et betteraves sucrières ; les exploitations de plus petite taille orientées vers le maraichage intensif, et les systèmes de production mixtes cultures-élevage. La majorité des terres cultivées est située dans la grande couronne, essentiellement donc en céréales et oléo-protéagineux. La betterave sucrière est surtout cultivée dans trois zones, au nord, au sud et dans l'est de la région. Les légumes se retrouvent surtout à proximité des agglomérations urbaines. Les systèmes mixtes, peu nombreux, sont localisés par exemple dans la zone de la Brie Laitière.

Dans ce contexte, une première analyse de la Région Ile-de-France concernant les quatre catégories de combinaisons de SES/Fonctions préalablement identifiées suggère les commentaires suivants :

(1) SES d'approvisionnement et fonctions liées. L'agriculture en Ile-de-France rend un service d'approvisionnement par hectare très élevé comparé à d'autres régions françaises, car cette agriculture est située sur les terres les plus productives du pays. Cependant, elle ne contribue que très peu à la fonction alimentaire locale, la céréaliculture dominant largement les productions et étant largement destinée au marché international et non local. Les produits frais, tels que fruits et surtout légumes, contribuent directement à cette fonction alimentaire (les 2/3 de la production est vendue localement en circuits courts) mais les surfaces consacrées à ces cultures diminuent rapidement. Les productions animales ont perdu de leur importance dans l'agriculture régionale et satisfont peu les besoins locaux. Le revenu par agriculteur a considérablement augmenté mais le revenu par hectare en grande culture a lui diminué. Le salaire des ouvriers agricoles augmente mais le nombre de travailleurs diminue fortement à l'échelle régionale. Les exploitations de grande culture comptent donc sur l'agrandissement des structures d'exploitation pour maintenir leur profitabilité.

(2) Les SES d'aménités paysagères et culturelles et les fonctions liées. Le paysage agricole francilien a été très simplifié au cours de la modernisation agricole, mais les larges paysages d'open-field sont appréciés des habitants comme un symbole d'ouverture et de liberté. L'agri-tourisme se développe rapidement dans les zones périurbaines. Le mode de vie agricole est apprécié généralement des agriculteurs eux même et des familles urbaines cherchent à s'en approcher (notamment par la pratique de jardinage associatif). Ainsi, l'agriculture joue un rôle important dans la construction d'une identité territoriale, notamment dans les parcs naturels régionaux, à travers les projets agri-urbains et d'autres outils de reconnaissance de l'agriculture.

(3) Le recyclage agricole des déchets urbains et les SES sous-jacents, de réduction des déchets et de fertilisation. En Ile-de-France, les déchets urbains partiellement ou totalement utilisés par l'agriculture sont les boues de station d'épuration, les déchets verts et les ordures ménagères organiques. De multiples facteurs influencent la relation offre-demande entre les agriculteurs périurbains et la population urbaine en ce qui concerne ces déchets urbains

(4) les fonctions environnementales qui caractérisent les contributions des agriculteurs au maintien de multiples SES de régulation et de soutien dans les agroécosystèmes et les habitats semi-naturels. L'agriculture en Ile-de-France a largement substitué aux services écosystémiques les intrants artificiels au cours du dernier siècle. Cette substitution a eu pour résultats une dramatique dégradation des SES et des impacts négatifs sur l'environnement, comme la dégradation de la fertilité des sols, le lessivage des nitrates, et des excès de pesticides, de même que le déclin de la biodiversité. Cependant, comparés aux aires fortement urbanisées, les sols agricoles restent d'abord bénéfiques à l'environnement. De nombreux instruments tentent d'encourager les agriculteurs à accroitre les fonctions environnementales, comme les mesures agri-environnementales, les certifications agriculture biologique et l'intégration de zones agricoles dans les trames vertes et bleues.

La rentabilité de l'agriculture n'est pas équivalente à sa productivité. La seule valeur économique de la production agricole ne suffit pas à lutter contre la régression de l'agriculture péri-urbaine. L'intégration des stratégies fondées sur les SES et sur la MFA peut amener des solutions effectives et mieux justifiées pour la préservation des terres agricoles périurbaines.

3. Gérer les friches dans les zones périurbaines : une approche multi-échelle dans le cas de la région Ile de France

Cette partie montre l'intérêt d'une approche multi-échelle pour traiter la question de la gestion des terres agricoles abandonnées en Ile de France. Cette approche combine une analyse des modes d'utilisation du sol à l'échelle régionale et des interviews dans deux petites zones, portant sur les perceptions de différents acteurs à propos des friches. Une analyse de trajectoires identifie tout d'abord les principaux changements d'usage des sols et la distribution spatiale et temporelle des friches dans la région Ile-de-France pendant la période 1982-2012. Ensuite, une classification des communes est proposée concernant les modalités de changement d'usages des sols et on étudie les facteurs qui permettent de distinguer et comparer les différentes situations d'enfrichement. Une troisième analyse au niveau régional porte sur l'évolution de l'aspect et la réutilisation éventuelle des terres en friche au cours du temps. L'objectif est de révéler les tendances temporelles et d'explorer les influences de certains évènements économiques, sociaux et politiques. L'analyse au niveau local des perceptions des acteurs face à l'enfrichement porte sur une série de questions : quels services écosystémiques rendent ou quels impacts négatifs ont les terres agricoles abandonnées ? Qu'est-ce que les acteurs attendent de ces terres en friche ? Comment les politiques locales s'emparent elles de ces questions ?

3.1. Principales trajectoires de changement d'usages du sol agricole et distribution des friches

Une sélection portant sur le classes de surfaces, et les structures spatiales a permis d'identifier 35 trajectoires de changements d'usage du sol pendant la période 1982-2012, portant au total sur 74,8% de la surface totale ayant subi des changements d'usage. Ces 35 trajectoires ont été regroupées en 10 catégories de changement d'usage du sol. La conversion des terres arables en prairies ou arboriculture a été la plus significative représentant 20,8% des changements d'usage du sol dans la région. La conversion inverse de prairies ou d'arboriculture vers de la grande culture ne représente que 7% des changements d'usage des sols. Les conversions de terres agricoles ou de zones naturelles vers la construction urbaine ou des espaces ouverts urbains est aussi importante, avec 12,8 et 14,7% du total des changements, respectivement. Les zones abandonnées et les zones à risque d'abandon représentent 12,8% du total, soit le même pourcentage que la conversion vers l'urbanisation. Les conversions en bois, forêts, terres de cultures ou étendues d'eau sont très faibles (3,7%, 1,2% et 1,2% respectivement). 0,5% du total concerne la conversion d'un espace ouvert urbain vers les terres arables : ils représentent probablement une mauvaise interprétation de zones en herbe pouvant correspondre aux aéroports dans la base MOS.

Les trajectoires montrent que les terres arables sont celles qui ont subi les plus lourdes pertes et ont principalement été converties en prairies (23694 ha), en terrains constructibles (15748 ha) et en espaces ouverts urbains (12806 ha). De plus, les friches provenant des terres arables (7229 ha) représentent environ la moitié du total des enfrichements. Les terres arables ont été en partie compensées par les prés (7229 ha). Le deuxième phénomène important est la réutilisation des terres abandonnées, en tant que terrains urbanisés (3670 ha), espaces ouverts urbains (3634 ha) et forêts ou bois (3376 ha). Et beaucoup moins a été réutilisé pour la culture (1454 ha).

Ces trajectoires de changements d'usages du sol dessinent des structures spatiales variées. Les résultats montrent que l'urbanisation a conquis en masse les terres arables sous forme de projets urbains de grande taille : comparés aux projets de construction, les changements vers des espaces ouverts urbains ont plus concerné de petites zones provenant de divers types d'usages antérieurs.

Si l'on regarde leur localisation spatiale, les conversions de terres agricoles ou naturelles vers les zones construites ou les espaces urbains ouverts se retrouvent surtout dans la ceinture entourant la proche banlieue. Cette ceinture d'urbanisation est connectée avec les centres urbains intermédiaires que sont les « Villes Nouvelles » et l'aéroport Charles de Gaulle. Les changements d'usage au sein même des catégories agricoles, par exemple de terres arables vers prés sont plutôt localisés au-delà de ces banlieues, dans des zones de caractéristiques plus rurales. De même dans ces zones au-delà des banlieues, les conversions de friches sont plus dispersées spatialement. Des communes avec un fort taux d'enfrichement apparaissent ainsi à la fois à proximité des banlieues s'urbanisant et dans les zones plus excentrées. Ce sont les communes les plus proches des banlieues qui convertissent le plus ces friches en zones construites ou en espaces ouverts urbains, et celles qui privilégient la construction ne coïncident pas avec celles privilégiant les espaces ouverts urbains, ces dernières se situant plutôt en bordure externe de la région. Les communes dont les friches se sont re-forestées correspondent plutôt à l'ouest de la Région ou aux bordures de la Forêt de Fontainebleau à l'est. Le retour à l'agriculture de friches agricoles concerne une minorité de communes, surtout en Seine et Marne, et quelques rares communes à l'ouest de la région.

3.2. Quatre groupes de communes dans différentes situations d'enfrichement

Une analyse factorielle de correspondance a permis de distinguer quatre groupes de communes, sur la base de 7 facteurs extraits de 20 variables 1) les surfaces et les localisations spatiales des principaux changements d'usage du sol (2) les pourcentages d'usages du sol stables (3) la population et le nombre d'agriculteurs dans la commune. Des tests non-paramétriques (Tests de Mann-Whitney) révèlent des différences significatives entre les quatre groupes. Ils représentent quatre situations relatives à l'enfrichement. En utilisant Google street views, des visites de terrains et la consultation de documents communaux ont permis de proposer des exemples concrets et de vérifier la pertinence de ces groupes.

Les quatre groupes de communes comprennent deux groupes en zone rurale et deux groupes en zone urbaine.

En zone urbaine, il existe un groupe fortement impacté par la périurbanisation et un autre comprenant des communes fortement urbanisées. Les raisons de l'enfrichement sont liées à l'urbanisation. Les terres à haut risque d'enfrichement sont des terres agricoles résiduelles incluses dans des zones urbanisées, ou comprises entre les zones urbanisées et les forêts. , ainsi que des parcelles coupées par des infrastructures. Les groupes impactés par la périurbanisation sont encore plus concernés par l'enfrichement. Ils comportent surtout les communes des Villes Nouvelles et l'aéroport de Charles de Gaulle. La Ville Nouvelle de Marne la Vallée est la plus concernée, suivie de Evry, Sénart, Cergy Pontoise et l'aéroport. A contrario, la Ville Nouvelle de Saint Quentin en Yvelines ne rencontre pas de problèmes d'enfrichement lié à l'urbanisation.

Dans les zones rurales, un groupe est fortement concerné par l'enfrichement du fait de facteurs non liés à l'urbanisation, et l'autre groupe est composé de communes restants ayant de fortes caractéristiques rurales. Les raisons de l'enfrichement sont alors essentiellement liées à de faibles potentialités agronomiques, sols pollués, existence de carrières de sable, zones humides de fond de vallée, sols forestiers pauvres. Ce groupe se rencontre surtout sur les boucles de la Seine, dont la boucle incluant les communes de Triel sur Seine et Carrières sous Poissy, dont d'importantes superficies de terres arables ont été abandonnées suites aux contaminations des sols par l'épandage incontrôlé de déchets urbains.

3.3. Tendances à l'enfrichement et réutilisation des terres abandonnées

Des séries temporelles portant sur l'aspect et la réutilisation des terres en friche permettent d'identifier les principales tendances ainsi que de mettre l'accent sur certains facteurs politiques ou sociaux ayant pu jouer à certaines dates. L'analyse est basée sur les principales trajectoires de changements d'usage des sols préalablement identifiées. Les conversions en friches ou depuis les friches ont été sommées pour chaque groupe de communes identifiées dans la section 3.2 et pour l'Ile-de-France dans son ensemble.

La tendance globale est que l'enfrichement a peu à peu surpassé en surface la réutilisation des terres en friche. La période d'étude peut être en cela divisée en deux parties :

(1) de **1982 à 1999**. Les surfaces en friches et les surfaces réutilisées augmentent toutes les deux pendant cette période. Les communes rurales ont vu la reforestation naturelle des terres abandonnées. Les communes touchées par l'urbanisation réutilisent quant à elles des terres abandonnées pour créer des espaces ouverts urbains.

(2) De **1999 à 2012.** La réutilisation de terres en friche devient moins courante dans les quatre groupes de communes. De substantiels enfrichements sont constatés de 2003 à 2008. Ils correspondent à l'arrêt des cultures sur les terres polluées de Triel-sur-Seine et Carrières-sous-Poissy ainsi qu'au retour des terres cultivées vers des prairies humides naturelles dans les zones humides des vallées. Pendant cette période, l'enfrichement en zones urbaines est influencé fortement par les projets urbains, comme en témoigne l'exemple frappant de Marne la Vallée. Contrairement à la première période, on constate peu de reforestation naturelle et la réutilisation des friches pour l'agriculture augmente légèrement.

3.4. Perception sociales des terres en friche à l'échelle locale

Des interviews ont été menées dans trois communes des boucles de la Seine (Vernouillet, Triel-sur-Seine et Carrières-sous-Poissy) et dans 6 du PNR de Chevreuse (Cernay-la-Ville, Le Perray, Auffargis, La Celle-les-Bordes, Saint-Rémy-L'Honoré, Saint-Rémy-lès-Chevreuse). L'enquête a tenté de couvrir les différents acteurs, élus, résidents, agriculteurs, associations environnementales… L'enquête individuelle a duré entre 30 mn et deux heures. Des guides d'enquête ont été conçus avant les interviews, légèrement différents selon les catégories d'acteurs.

Les principales questions ont porté sur : (1) la localisation des friches agricoles en relation avec les activités de la personne interviewée (2) les perceptions de l'interviewé au regard des friches (image positive, impacts négatifs ressentis, (3) la compréhension des services écosystémiques pouvant être fournis par les friches (4) le souhait d'une gestion de ces friches. En plus de conversations semi-dirigées, les interviewés devaient remplir trois tableaux en sélectionnant parmi une liste d'items ceux qui correspondaient le mieux à leurs perceptions et souhaits. Nous avons obtenu un total de 49 interviews complètes. La transcription des questions/réponses et une analyse approfondie qualitative ont été conduites afin de comparer les perceptions des différents acteurs dans les deux zones concernées.

Les résultats laissent entendre qu'il existe des différences notables entre acteurs et entre zones. Les agriculteurs et les résidents perçoivent les friches en lien étroit avec leurs expériences personnelles, de ce fait les connaissances et perceptions sur les friches varient beaucoup. Les élus (maire) et planificateurs urbains (service d'urbanisme) de même que les responsables associatifs ont une image assez complète du panorama des friches dans leurs communes. Les responsables du PNR de Chevreuse ont à charge de coordonner les intérêts de différents acteurs, agriculteurs, habitants et autres et donc travaillent avec une large vision des intérêts possibles de ces friches.

Tant le PNR de Chevreuse que la boucle TCV (Triel-sur-Seine, Carrières-sous-Poissy et Vernouillet) reconnaissent aux friches le caractère d'espaces naturels et sauvages, qui procurent des habitats divers pour la faune sauvage. De tels espaces suscitent donc des sentiments positifs chez ces personnes. Elles ressentent cependant quelques sentiments négatifs dûs à la présence de gros gibier (sangliers), et de l'utilisation possible de ces friches comme décharge illégale ou comme zone de camping non autorisée. TCV reconnait plus la valeur de ces friches en termes de découverte de la biodiversité. La plupart des acteurs du PNR ne considèrent pas que ces friches aient un intérêt particulier pour le loisir ou sur le plan esthétique. Ils ne les valorisent pas non plus particulièrement comme ayant un intérêt écologique, mais seraient plus enclins à favoriser des activités agricoles incluant des objectifs écologiques sur ces zones.

Nous avons aussi réalisé des analyses quantitatives par table binaire en extrayant des informations des trois tableaux remplis par les interviewés. La table binaire représente les perceptions de chaque acteur concernant les SES principaux, et les dis-services aussi, qu'ils attachent aux friches, et leurs opinions sur les possibles usages futurs de ces friches, entre construction, activité agricole, habitats écologiques ou parcs récréatifs respectivement. Un classement hiérarchique de groupes, basé sur les notes binaires des SES et des dis-services, a conduit à distinguer trois groupes d'acteurs, qu'un test binomial (au seuil de 5%) a permis de caractériser.

Les résultats montrent que les déterminants de ces trois groupes d'acteurs sont "les potentialités agricoles" (Groupe 1), qui souhaite un retour vers un usage agricole des friches "les valeurs environnementales " (Groupe 2) qui met en avant un usage agricole mais avec une forte composante environnementale, "les valeurs récréatives" (Groupe 3) qui apprécie particulièrement les possibilités récréatives de ces zones.

4. Influences des échelles spatiales sur la relation "offre-demande" dans le recyclage agricole des déchets urbains par l'agriculture périurbaine d'Ile-de-France

Cette partie de la thèse analyse l'influence des différentes échelles sur la relation entre offre de déchets urbains et leur utilisation (demande) par l'agriculture francilienne, avec l'objectif de fournir des pistes pour une gestion multi échelle de cette relation. L'étude s'est concentrée sur deux déchets urbains, les boues de station d'épuration et les composts de déchets verts, qui sont les plus importants en termes d'utilisation agricole. De plus ils représentent les deux grandes classes de déchets urbains, l'un classé comme « déchet » (les boues) l'autre comme « produit », le compost de déchets verts.

L'application de boues sur des parcelles agricoles nécessite l'obtention d'un plan d'épandage et est sous le strict contrôle de règlements conçus pour limiter les risques environnementaux et sanitaires. Le compost de déchets verts, de même que le co-compostage entre déchets verts et boues, ont au contraire un statut de "produit", considérés comme un fertilisant ou un produit amendant. Pour vendre un compost il faut remplir deux conditions (1) détenir une licence ou une autorisation provisoire pour la vente ou l'importation délivrée par le Ministère de l'Agriculture (2) satisfaire aux standards de composition des décrets français d'application des normes européennes, notamment la norme NFU-44-051 pour le compost de déchets verts et la NFU 44-095 pour le co-compost. La responsabilité d'incidents dus à des produits pollués est dans ce cas transférée du producteur vers l'utilisateur, ces composts et co-composts étant vendus sur le marché.

Cette étude adopte aussi une approche multi-échelles, partant d'une analyse régionale des relations entre offre et demande relatifs à l'épandage agricole des boues, et sur des recherches à l'échelle locale auprès de parties prenantes. L'étude révèle ainsi l'importance de l'échelle sur cette relation offre-demande pour les deux matières étudiées.

4.1. Cadre régional de la relation offre-demande pour l'épandage agricole de boues de station d'épuration

4.1.1. La production de boues de station d'épuration en Ile-de-France

Les trois plus grosses stations (>100 000PE) représentent 84.2% de la production régionale de boues en 2013. La production atteint 96.4% si on y rajoute les 54 stations de moindre importance (10 000-100 000 PE). Ainsi, la production et le recyclage des boues est surtout une affaire de grosses implantations dans la Région.

L'épandage sur les terres agricoles est la principale utilisation des boues, surtout pour les stations de plus petite capacité, notamment celles < 2000 PE en substitution l'incinération ou du compostage. Au contraire, cette proportion décroit progressivement pour des capacités comprises entre 10.000 et 100.000 PE, avec une forte augmentation de l'incinération et du compostage dans ces cas. Les stations intermédiaires connaissent des pourcentages d'épandage fluctuant entre années, mais avec un pourcentage relativement stable du compostage. Les plus grosses stations (>10.000 PE) ont des stratégies variées et leur pourcentage d'épandage sur les terres agricoles est le plus faible des quatre tailles de station. L'incinération et le compostage y jouent un grand rôle. Cependant, elles restent les plus gros fournisseurs de boues pour l'épandage vu les quantités qu'elles traitent.

Les stations ont été classées en 4 catégories au regard du rapport entre production de boues (Qp) et épandage agricole (Qa) au cours des 4 années entre 2010 et 2013 La première catégorie (Qp > 1000 tDM and Qa > 1000 tDM DM dry matter, matière sèche) comprend 21 stations, deux d'entre elles faisant partie du SIAAP (Syndicat Interdépartemental pour l'Assainissement de l'Agglomération Parisienne): la station Seine-Aval à Achères et la station Seine-Amont à Valenton. La deuxième catégorie (Qp < 1000 tDM mais Qa > 1000 tDM) comprend deux stations de Seine-et-Marne: Coulommiers et Fontenay-Tresigny. La troisième catégorie (Qp > 1000 tDM mais Qa < 1000 tDM) comprend 18 stations, qui recourent plus à d'autres formes d'utilisation des boues que l'épandage. Les 421 stations restantes entrent dans la quatrième catégorie (Qp < 1000 tDM et Qa < 1000 tDM), elles sont situées surtout dans les zones les plus rurales et souvent le long des réseaux hydrographiques.

Les zones de collectes des eaux à traiter ont été visualisées pour les stations pour lesquelles soit Qp soit Qa sont supérieurs à 1000 DTM. Ces zones représentent l'aire d'origine de 95% des boues produites et de 92% des zones d'épandage de la Région. La zone de collecte du SIAAP est la plus importante et la principale source de boues d'épandage agricole. Ses zones adjacentes ont aussi d'importantes quantités produites et épandues. Une autre zone importante est le département de la Seine-et-Marne, le plus rural des départements d'Ile-de-France. La production de boues y est importante mais préférence est donnée à d'autres devenirs des boues que l'épandage. Les stations qui ont une forte production de boues mais relativement peu d'épandage se situent plutôt dans l'ouest de la Région. Les stations en bordure de l'agglomération parisienne comptent surtout sur l'incinération ou la mise en décharge et celles situées plutôt en zones rurales ont tendance à se tourner de plus en plus vers le compostage afin de transformer le "déchet" boues en "produit".

4.1.2. Potentialités communales concernant les terres agricoles aptes à recevoir des boues

En combinant la distribution des terres agricoles avec les critères inclus dans les règlements, on peut identifier les communes qui ont un potentiel important d'épandage des boues. Le registre parcellaire graphique (RPG) indique la distribution spatiale des terres agricoles. Les critères restrictifs de la réglementation concernent la pente des terrains, la distance aux cours d'eau, l'existence d'une étendue d'eau, la proximité d'habitations, et les sites de production d'eau potable. Cette quantification des aires communales aptes à recevoir des boues a été réalisée en trois étapes : (1) l'identification des parcelles de "Grande Culture" –les parcelles maraichères ne pouvant pas recevoir de boues, (2) le retrait des surfaces qui ne rentrent pas dans la réglementation (3) l'évaluation du potentiel surfacique de la commune pouvant permettre l'épandage de boues, en relation avec la structure spatiale des parcelles retenues.

L'analyse a permis d'identifier 427 287 ha de parcelles agricoles susceptibles de recevoir des boues dans la Région, représentant 74.9% des terres déclarées dans le RPG. 1046 communes de la région sont concernées. 30,6% d'entre elles ont entre 100 et 300 ha concernés, ce qui représente environ 14.4% des terres de ces communes. 21.3 % des communes a entre 500 et 100 ha de parcelles potentiellement utilisables pour l'épandage de boues (soit 36% des terres, le pourcentage le plus fort enregistré), 80 communes ont entre 100 et plus de 2600 ha concernés (soit 26,9% des terres pouvant recevoir des boues). Enfin, 195 communes ont moins de 100 ha et ne représentent que moins de 2% des surfaces concernées totales.

Les communes avec la plus importante fraction de l'espace épandable (> 1000 ha) sont surtout sur la plaine de Beauce, dans le sud-ouest, le Gâtinais au Sud et le plateau de Brie à l'est. Le plateau du Vexin dans le nord-ouest et la Butte de Dammartin dans le Nord Est ont un grand nombre de communes totalisant de 500 à 1000 ha de terres potentiellement épandables. Dans plusieurs autres zones, les communes ont entre 300 et 500 ha épandables, le plus souvent : la Plaine de Versailles dans l'Ouest, le Hurepoix, la vallée de la Bassée au Sud-est sous le plateau de Brie, et le pays de Vieille France au nord de l'agglomération parisienne.

Le schéma global des flux montre une discordance entre les principaux lieux de production des boues et la distribution des terres potentiellement épandables. La zone d'épandage du SIAAP concerne seulement quelques communes à ses abords, ayant entre 500 et 1000 ha épandables. Au sein de cette zone, seul le Plateau de Saclay présenterait une surface potentielle importante. Au Nord-est, la zone d'épandage de la station de Cergy-Pontoise-Neuville-sur-Oise et celle des Mureaux couvrent des communes avec de fortes surfaces épandables. De même la station de la Ville Nouvelle Saint-Quentin-en-Yvelines doit aller plus à l'ouest et apporter ses boues dans la Plaine de Versailles, voire même hors Ile-de-France dans le Drouais. Dans le département de Seine-et-Marne, les stations de Presles-en-Brie, Setp-sorts, Provins, Coulommiers, et Fontenay-Trésigny ont toutes d'importantes zones potentielles d'épandage. Les deux stations du Gâtinais, Grande-Paroisse et Nemours ont choisi de convertir toute leur production de boues en compost.

4.1.3. Les flux spatiaux de boues dans les épandages en Seine-et-Marne

Une étude sur 659 parcelles de l'Observatoire des Eaux du Conseil Général de Seine-et-Marne a publié en 2010 un document fournissant des données utiles pour examiner les flux réels des stations vers les exploitations agricoles en 2009. Au, 84 685 t (poids brut) de boues ont été épandues sur 136 communes et 5573 ha de terres agricoles. Cette surface ne correspond qu'à seulement 2,2% du total des terres potentiellement épandables du département.

La plupart de ces boues ont été épandues dans une zone différente de la zone de production. Les plus forts épandages se sont concentrés dans une zone au nord de Fontainebleau, et proche de l'agglomération parisienne. Une autre zone est située au nord-est de la Seine-et-Marne. A Fontainebleau, les communes ont reçu beaucoup de boues provenant de stations extérieures, au nord-est, les communes ont surtout reçu des boues provenant d'une seule station extérieure. Les communes qui épandent leurs propres boues sont surtout dans le centre et le sud du département. En bordure des deux zones précédentes, on trouve des communes qui à la fois épandent leurs propres boues et celles de stations externes.

Pour les stations qui dépendent fortement de l'épandage agricole, on constate deux types de flux (i) vers les zones rurales vastes de l'est de la Seine-et-Marne, '(2) vers les communes alentour. Les plus grosses stations tendent à livrer leurs boues vers des zones plus lointaines, alors que pour les plus petites, la proximité géographique des zones d'épandage est importante. Seule une minorité de grosses stations appliquent des boues dans les zones de collecte des eaux. Le SIAAP applique l'essentiel de ses boues en dehors de l'Ile-de-France. Certaines grosses stations sont cependant concernées par la problématique du service de recyclage agricole des boues dans l'agriculture périurbaine, leurs boues provenant elles des zones urbaines.

4.1.4. Estimation d'un schéma régional des successions de cultures

L'épandage de boues sur des parcelles doit prendre en considération d'autres facteurs que ceux liés à la réglementation examinée dans la section 4.1.2. La succession de cultures sur les parcelles est importante car les épandages de boues doivent coïncider avec les besoins des plantes en croissance tout en respectant la législation. De ce fait, toutes les cultures ne peuvent pas recevoir de boues et la surface réellement épandable une année donnée est inférieure à la surface potentielle précédemment calculée, elle doit tenir compte des successions de culture sur les parcelles.

L'analyse des parcelles épandues dans l'étude spécifique de Seine-et-Marne révèle les préférences des agriculteurs pour apporter des boues sur certaines cultures. Il y a deux grandes périodes possibles d'épandage : l'une au printemps, avant le semis de cultures de printemps comme le maïs, l'autre de début juillet à fin octobre, après la récolte des colzas, des blés, et avant le semis de ces mêmes cultures. Les boues sont très majoritairement appliquées avant le semis des cultures. En 2009 en Seine-et-Marne, la majorité des épandages a eu lieu en août, après la récolte de tous les blés et avant le semis du colza ou des nouveaux blés. Pour les parcelles destinées à porter du blé ou des betteraves sucrières, l'épandage a eu lieu pendant tout le mois d'août. Pour les parcelles revenant du colza, l'épandage a eu lieu pendant la première moitié d'août surtout. Les terres destinées à recevoir du maïs au printemps sont épandues surtout en septembre. Le colza est la culture sur laquelle a eu lieu le plus d'épandage (33,8% du total, suivi par le blé (20,4% ; mes betteraves sucrières (22.1%, le maïs (14.3%) Le reste des cultures recevant des boues compte pour moins de 10% des surfaces épandues. Le choix privilégié du colza provient du fait qu'il peut absorber beaucoup d'azote en début de cycle en automne, que donc l'application de boues peut être rapidement valorisée et permet ainsi de réduire les risques de lessivage d'azote pendant l'hiver.

Pour estimer les principales successions de culture au sein des terres de Grande Culture, nous avons sélectionné les parcelles du RPG qui ne portent qu'une culture par an durant les 5 années sur lesquelles nous avions des données (de 2006 à 2010). Ces parcelles représentent 27,8% de la surface totale concernée par le RPG en 2010. Nous avons regroupé les cultures présentes en neuf catégories et reconstitué les successions de culture. Nous interprétons alors (i) en termes de nombre de cultures apparaissant au cours des 4 ans (n = 2 à 5) (ii) la combinaison des types de cultures dans chaque polygone, sans distinguer l'ordre d'entrée de chaque culture (iii) les trajectoires en considérant au cours du temps le nombre d'occurrences des combinaisons définies en (2).

Les résultats suggèrent que la rotation historique "Jachère-Blé-Culture de printemps" largement dominante dans la région du 16ème au 19ème siècle inclus, a eu une influence notoire sur les successions de culture modernes. Les successions actuelles se construisent fréquemment sous le schéma « Tête d'assolement"-Blé-Culture de printemps, dans laquelle la tête d'assolement est fréquemment le colza , parfois le maïs, des cultures industrielles ou des oléo-protéagineux, et la culture de printemps, si elle est fréquente (maïs, betteraves sucrières, orge de printemps) n'est pas systématique. La succession de culture est souvent l'application d'un modèle de base avec quelques alternatives. Par exemple, la succession Colza-Blé-Orge est fréquemment adoptée dans le Hurepoix et le plateau de la Beauce, mais aussi dans le Bocage Gâtinais au sud et la Vallée de la Bassée au sud-est. La succession sur deux ans Colza-blé est surtout fréquente dans le Drouais, mais des successions sur quatre ans de type Colza-blé- maïs-blé est fréquente sur la Plaine de Versailles, alors que la succession avec Maïs-Blé-pois protéagineux-Blé, est fréquente en Brie laitière. Comme l'année de la tête d'assolement sur une parcelle, notoirement le colza, est une période favorable pour l'épandage des boues, il apparait que la disponibilité de terres à épandre n'est pas un problème dans la région.

4.2. Influences multi-échelles sur l'offre et la demande des déchets urbains à recycler dans l'agriculture périurbaine

L'analyse des influences multi-échelles sur la relation offre-demande s'est basée sur des interviews auprès d'acteurs locaux dans deux zones, le plateau de Saclay et la Plaine de Versailles. Ces deux zones ont été choisies notamment pour représenter des structures d'offres en boues différentes (nombreuses stations dans la Plaine, dépendance du SIAAP pour le Plateau de Saclay). Les interviews ont concerné différentes catégories d'acteurs, des producteurs de déchets, des agriculteurs, des élus, des représentants des habitants, des personnes en charge d'établir des réglementations et d'autres acteurs. Les enquêtes ont duré de 30 mn à 2 h sous forme d'une conversation libre autour d'un guide d'enquêtes. Les questions ont inclus d'abord des informations générales sur les acteurs, les pratiques de ces acteurs et leurs perspectives pour le futur du recyclage des déchets urbains. Une transcription intégrale a été réalisée pour la plupart des interviews. Des analyses de ces matériaux et de documents de référence ont été réalisées (directives européennes, lois et décrets français) et ont conduit à élaborer un schéma montrant les facteurs multi-échelles influençant les relations offre-demande à propos de l'utilisation agricole des boues et des composts de déchets verts.

Une dernière analyse a permis de distinguer différents catégories d'agriculteurs au regard de leurs pratiques et de leurs perceptions concernant l'usage des déchets urbains.

4.2.1. Un cadre d'études des influences multi-échelles sur la relation offre-demande

La clé de ce cadre est l'équilibre entre l'offre de déchets urbains visant l'élimination de ces déchets (demande urbaine) et la demande pour la fertilisation des cultures (demande agricole). Les facteurs qui influencent cet équilibre incluent des facteurs à l'échelle individuelle, à l'échelle locale et des réglementations à l'échelle supérieure. A l'échelle locale, ces facteurs comprennent les pressions provenant des filières agro-alimentaires (pouvant s'opposer à l'usage de boues dans les parcelles par exemple), des problèmes de voisinage, des facteurs internes relavant du choix des agriculteurs et la disponibilité de fertilisants de substitution. De même, la demande urbaine d'élimination des déchets peut être influencée par des problèmes de voisinage, des facteurs internes aux producteurs de déchets, et la possibilité de recourir à des devenirs alternatifs, comme l'incinération, le compostage ou la méthanisation. La population urbaine ne participe pas de fait à la gestion directe des devenirs de ses déchets. Elle se désintéresse de ses déchets une fois payées les taxes sur l'eau et sur le ramassage des ordures ménagères ou sur les déchets verts auprès des services municipaux. Les producteurs de déchets sont de fait les parties prenantes les plus directement concernées par la question du devenir des déchets urbains.

L'échelle locale peut être constituée par une commune, un groupe de communes ou un territoire comme la plaine de Versailles ou le Plateau de Saclay, organisé en "projets agri-urbains », associations dédiées à la collaboration entre agriculteurs, élus et résidents. Améliorer la cohésion territoriale dans ces projets a notamment passé par tenter d'intégrer les aspects fertilisations et les aspects réduction des déchets dans la gestion des déchets urbains. Les réglementations à l'échelle supérieure s'intéressèrent aussi à la fois à la question de l'élimination des déchets et à celle de la fertilisation, mais manquent aujourd'hui d'intégration entre les deux aspects.

Ces facteurs interagissent à diverses échelles. Les règlementations se sont renforcées et sont devenues de plus en plus strictes dans la prévention des risques environnementaux. Les producteurs de déchets et les agriculteurs ont tous senti augmenter les contraintes provenant des instances supérieures, dans les traitements des déchets, dans leur utilisation comme fertilisant agricole. Les réglementations ont quant à elles peu de capacités à prendre en charge les problèmes qui se posent au niveau local à propos de l'épandage des boues. En fait, aux côtés des contrôles par étapes sur les pratiques, d'autres facteurs sociaux sont importants à prendre en compte pour améliorer la compréhension mutuelle entre producteurs de déchets et agriculteurs, et ce pour avoir un effet positif sur l'utilisation agricole des déchets urbains. En fin de compte, les choix individuels peuvent fortement augmenter ou diminuer la capacité locale de recyclage agricole de déchets urbains.

4.2.2. Catégories d'agriculteurs concernant l'usage des déchets urbains

Une classification a été réalisée en sept groups pour catégoriser les relations entre les perceptions des agriculteurs et leurs pratiques concernant les déchets urbains. Cette catégorisation a été réalisée à partir des 18 entrevues approfondies qui ont été réalisées (15 sur la Plaine de Versailles et 3 sur le Plateau de Saclay). L'objectif est d'identifier les facteurs qui ont effectivement influencé le choix des agriculteurs, plus que de prétendre avec un petit nombre de cas à élaborer une réelle typologie. Voici ces sept catégories:

(C1) Utilisateurs de boues, incluant trois agriculteurs engagés dans des plans d'épandage de boues de la station d'épuration de Plaisir. Ces agriculteurs ne pratiquent plus d'épandage parce que la station de Plaisir a changé de stratégie en 2012 (arrêt du séchage car augmentation trop forte du prix du gaz) et envoie maintenant les boues jusque-là épandues, vers une station de co-compostage hors de l'Ile-de-France.

(C2) Passage de l'épandage de boues à celui de compost de déchets verts du fait de fortes oppositions locales aux boues. Cas d'un exploitant de la Plaine de Versailles.

(C3) Passage de l'épandage de boues à celui de compost de déchets verts du fait du renforcement des contraintes réglementaires (un autre agriculteur de la plaine de Versailles)

(C4) Producteurs et utilisateurs de compost de déchets verts qui ne font pas confiance aux boues de station d'épuration. Comprend deux producteurs de compost de déchets verts de la Plaine de Versailles et un du Plateau de Saclay, ainsi que 4 agriculteurs qui prennent du compost, un dans le plateau de Saclay et un sur la Plaine de Versailles.

(C5) Utilisateurs d'engrais organiques non issus de déchets urbains, et qui n'ont pas confiance dans les boues (3 agriculteurs de la plaine de Versailles).

(C6) Agriculteurs qui n'utilisent pas de produits organiques et qui n'ont pas confiance dans les déchets urbains en général, 3 exploitants de la Plaine de Versailles.

(C7) Pas d'utilisation de boues, du fait de l'interdiction faite par le propriétaire foncier, cas d'un agriculteur du Plateau de Saclay.

Quand l'agriculteur n'a pas confiance dans les déchets urbains, il n'est pas incité à en prendre pour des raisons économiques. Parmi les fertilisants organiques, il a été montré que les agriculteurs ont plus confiance dans les effluents d'élevage, puis dans les composts de déchets verts et en dernier dans les boues. Quand l'agriculteur accepte les boues, il peut arriver que des facteurs extérieurs l'amènent à interrompre ses épandages, que ce soit le changement de stratégie de la station d'épuration, les problèmes avec les résidents, des raisons administratives ou l'opposition du propriétaire ou de la filière à laquelle il vend ses produits.

5. Discussions Générales

5.1. Un cadre intégré des MFA et des SES pour l'agriculture périurbaine

Cette thèse a proposé un cadre intégré des SES et de la MFA qui identifie la MFA comme fondée sur les contributions des agro-écosystèmes, c'est-à-dire les services écosystémiques, et le rôle des agriculteurs pour transférer, ou pas, les SES comme fonctions de l'agriculture. L'identification de quatre catégories de relations fonctions/SES permet d'apporter plus de précisions quant à la nature même de la MFA et à améliorer la mise en œuvre réelle des SES. Le cadre intégré rend explicite les mécanismes qui supportent les différentes fonctions agricoles. La cascade des SES explique comment les structures des écosystèmes et les processus (par exemple la structure du sol, la biodiversité) contribuent à la délivrance de ces SES (approvisionnement en nourriture, eau, aménités paysagères etc). Les fonctions environnementales peuvent ainsi en être justifiées. Le cadre intègre à son tour les rôles des facteurs socio-économiques. Améliorer les SES d'approvisionnement en nourriture et matières premières ne passe pas forcément par l'amélioration de la fonction alimentaire ou du bénéfice économique.

Définir les SES et la MFA est sujet à beaucoup de controverses. La question restante est comment intégrer dans ce cadre les fonctions diverses discutées dans la littérature. Deux pistes de réflexion à ce propos : l'une, qui est que les liens entre MFA et les SES sous-jacents sont différents selon les sites géographiques et l'évolution des systèmes agricoles ; l'autre, qui est que certaines fonctions (Niveau 1) sont directement dépendantes des interactions entre les SES et les facteurs socio-économiques (principalement ceux que nous avons décrits dans le chapitre 3), et d'autres fonctions (Niveau 2) résultent d'interactions entre les fonctions de niveau 1 et de nouveaux facteurs socio-économiques. Les investigations locales devraient être capables de clarifier les contributions des SES et celles des systèmes socio-économiques pour la réalisation d'une fonction de l'agriculture.

Les approches intégrées des SES et de la MFA doivent aussi considérer les interactions entre différents SES et différents fonctions. Les méthodes d'investigation doivent être différentes, notamment pour prendre en compte directement les facteurs socio-économiques. L'usage excessif d'une fonction peut se faire au détriment d'autres fonctions. Les interactions entre SES et fonctions peuvent aussi déboucher sur des opportunités pour préserver l'agriculture périurbaine. Il est ainsi intéressant pour de futures études et pour la définition de politiques, de mieux étudier les combinaisons de fonctions entre production de nourriture, circuits courts, agriculture biologique et agri-tourisme.

5.2. Relations mutuelles entre usage du sol et SES/MFA

De nombreuses études sur les SES ont cherché à mettre en évidence les influences du changement d'usage des sols sur les SES. Le fait de combiner les approches SES avec celles de la MFA permet de mieux considérer les interactions entre ces changements d'usage du sol, les SES et les fonctions. Les demandes sociales visant certains types d'agriculture se traduisent par certains schémas d'usages du sol, lesquels à leur tour engendrent la fourniture de divers SES. Ces SES sont le support des fonctions que peut remplir l'agriculture. Leur changement impacte nécessairement les fonctions remplies par l'agriculture et peut conduire les agriculteurs à modifier leurs pratiques. Les demandes sociales sur l'agriculture dépendent cependant aussi d'autres facteurs, comme des préférences individuelles ou certaines politiques. Cela peut ainsi prendre du temps de traduire les demandes sociales sur les SES en pratiques agricoles.

La gestion des friches dans les zones périurbaines est un bon exemple pour révéler les multiples mécanismes à l'action entre usages des sols et SES. Les sols agricoles sont mis en friche lorsque leur valeur agronomique n'est plus satisfaisante, en premier lieu. Dans ce cas, c'est la fonction productive de l'agriculture qui est seule considérée. Les études sur les perceptions locales suggèrent toutefois que les attentes sociales vont de plus en plus vers une agriculture multifonctionnelle. Le processus conduisant de l'enfrichement au re-développement d'une agriculture multifonctionnelle est le résultat de nombreuses interactions ente usages des sols et SES/fonctions. L'enfrichement peut conduire des habitants à réaliser que la terre abandonnée remplit de fait un bouquet de services, qui les amène à se rendre compte de l'ensemble des fonctions que peut remplir un sol.

5.3. Services mutuels entre acteurs dans le recyclage agricole des déchets urbains

Le recyclage agricole de déchets urbains peut être vu comme un service mutuel entre producteurs de déchets et agriculteurs, notamment dans le cas de l'épandage agricole de boues urbaines. Les principes actuels d'épandage à zéro coût pour les agriculteurs et le fait que les producteurs de boues conservent la responsabilité en cas de problèmes sont appréciés des agriculteurs et acceptés par les producteurs. La population urbaine, à l'origine de ces boues, est cependant souvent opposée à leur usage sur les terres agricoles dans les zones périurbaines d'Ile-de-France. La non communication entre la population urbaine et les producteurs de boues intensifie cette opposition. Celle-ci se traduit souvent par la délégation croissante de l'assainissement à des professionnels et non plus aux communes, ce qui accroit encore le phénomène de non communication.

Sur la question délicate de savoir s'il faut que les agriculteurs soient payés pour prendre des boues, au nom du service de réduction des déchets qu'ils rendent à la ville, les producteurs de boues ont souvent une réponse négative, en arguant du fait que les boues rendent aussi un service de fertilisation pour les systèmes de production agricole et ont ainsi une valeur agronomique et économique. Les agriculteurs y sont eux aussi opposés car ils considèrent qu'ils rendent un service à la collectivité, et ils ne veulent pas risquer d'encourir une responsabilité. Ceci conduit à des questions intéressantes au sujet du paiement pour service écosystémique rendu (PSE). Les PSE ne doivent pas être considérés seulement comme un transfert monétaire aux agriculteurs. Il faut en effet mieux comprendre les relations entre les différents acteurs, non seulement du point de vue des mécanismes biophysiques, mais aussi du point de vue des dimensions économiques et sociales.

5.4. Influences multi-scalaires et discordances entre échelles

Dans des systèmes socio-écologiques comme ceux qui existent en agriculture, les discordances entre échelles sur les processus écologiques et les attitudes institutionnelles sont responsables de mauvaises gestions des ressources naturelles. Pour l'agriculture périurbaine d'Ile-de-France les échelles physiques et écologiques vont du champ à la vallée ou à l'aire de captage, jusqu'au paysage global. Les échelles institutionnelles concernent l'échelle de la ferme, de la commune, des intercommunalités, du département et de la région, et jusqu'aux instances nationales et européennes qui édictent certaines réglementations. Les risques de discordances entre elles sont ainsi nombreux.

La politique agricole commune (PAC) doit faire face à ce "syndrome du petit gestionnaire" bien éloigné des décideurs européens. Par exemple, les agriculteurs qui produisent essentiellement pour le marché international peuvent être amenés à surexploiter les écosystèmes quelques soient les efforts au niveau européen pour tenter de les protéger. De même, il est difficile pour le niveau européen de gérer les problèmes environnementaux régionaux comme les pertes de biodiversité, les lessivages de nitrates etc. Ces problèmes, nés des systèmes de production agricole, les dépassent cependant dans leurs effets sur l'environnement.

Des instruments efficients existent cependant pour tenter de connecter les bénéfices à des échelles supérieures, avec ceux ressentis à des échelles inférieures. De nombreuses études sur les SES proposent de créer des marchés pour les biens non marchands comme la biodiversité ou le changement climatique. Mais les parties prenantes à l'échelle locale peuvent apprécier des bénéfices autres que des revenus monétaires, comme on le voit dans l'exemple des épandages de boues. Le développement d'indicateurs globaux pour les agriculteurs doit se faire fort prudemment. Des mesures orientées sur des résultats peuvent être intéressantes pour les réglementations concernant l'usage des sols agricoles, la valorisation des déchets ou d'autres exemples possibles.

5.5. Discussions sur la méthodologie

Les études détaillées sur un SES particulier ou sur un usage des sols sont souvent pleines d'enseignement, et peuvent amener des informations non détectées dans une évaluation globale ou une représentation cartographique des SES, notamment pour détecter l'influence de facteurs socio-économiques. Notre intention première était d'analyser quels étaient les SES/fonctions que les friches dans un territoire pouvaient apporter aux habitants, de même pour la valorisation agricole des déchets urbains pour les agriculteurs. Il s'avère que les choses sont bien sûr plus complexes. Les friches sont un usage du sol en évolution constante et variée, et les SES ou fonctions remplies sont différentes selon le contexte géographique et le contexte social. La conversion d'une friche en un autre usage n'est ainsi par déterminée seulement par les SES que cette friche procure aux habitants, mais aussi et souvent d'abord par ce que ces habitants attendent des formes futures. Le recyclage des déchets urbains n'est pas qu'un seul service, mais repose de fait sur deux services écosystémiques. De plus dans ce cas, la relation entre agriculteurs et habitants est médiatisée par les producteurs de déchets

La comparaison entre les deux études est intéressante pour formuler quelques conclusions. Les friches, comme les déchets urbains, sont à la fois des « ressources » et des « déchets ». Ils nécessitent chacun une gestion adaptée, car ces modes de gestion peuvent changer fortement les fonctions remplies par ces « déchets ». Les quatre territoires que nous avons étudiés sont proches les uns des autres mais, de fait, offrent des contrastes importants, tout en étant reliés. L'histoire de la pollution par des déchets urbains mal gérés dans la zone TCV a donné à certains dans la Plaine de Versailles une mauvaise image du recyclage agricole des déchets urbains, et les enfrichements consécutifs à TCV restent une crainte pour les agriculteurs de la Plaine de Versailles.

Les résultats prouvent qu'une approche multi-échelle combinant le niveau régional avec les perceptions plus locales est importante. On voit par exemple dans nos études que les parties Est et Ouest de la région sont assez différentes sur ces deux sujets. La partie Est, dominée par des caractéristiques rurales, est surtout composée de terres agricoles. La partie Ouest est composée d'un mix entre terres agricoles, forêts, zones à intérêt environnemental et centres de développement urbain, et elle est le siège de nombreuses interactions entre acteurs. Les recherches à l'échelle territoriale doivent prendre en compte ce découpage régional.

Les discordances entre les résultats à l'échelle régionale et ceux à l'échelle locales aident de fait à identifier les problèmes d'insuffisance de données à l'échelle régionale et/ou les méthodes même d'investigations à cette échelle. Ces discordances peuvent venir par exemple d'un problème de données statistiques et/ou des impressions faussées des acteurs à l'échelle locale.

5.6. Implications opérationnelles

Comparée à la reconquête forestière ou à l'urbanisation de friches, leur retour à l'usage agricole apparait comme une forte demande des urbains, suivie de l'usage pour les loisirs. Ceci suggère l'existence d'une demande sociale pour des formes d'agriculture multifonctionnelle dans les zones périurbaines, qui combinent des fonctions environnementales, paysagères, récréatives et autres et qui s'adaptent à la fragmentation de l'espace dans les zones urbanisées. Dans une zone plus rurale comme le PNR de Chevreuse, l'objectif premier est de maintenir un paysage ouvert, alors que dans les villes nouvelles comme Marne la Vallée ou Sénart, le premier objectif est de développer de nouvelles formes adaptées à la fragmentation spatiale. L'agriculture traditionnelle mécanisée d'Ile-de-France ne répond pas à ces nouvelles attentes. Il s'agit pour les autorités locales comme pour les agriculteurs de réfléchir ensemble à des transitions vers cette multifonctionnalité, ce qui est en partie le cas dans les projets agri-urbains de la Région.

Pour le recyclage agricole des déchets urbains, les principes actuels de zéro cout sont satisfaisants des deux côtés (agriculteurs et producteurs). Il est cependant urgent d'accroitre la communication entre les différentes parties prenantes, en incluant la population urbaine à l'origine de ces boues. Mais le problème principal nous semble être de simplifier les procédures et d'offrir des arguments simples et des preuves convaincantes de la sûreté des boues à épandre. Là encore, des initiatives locales de cohésion territoriale et un management régional des déchets urbains impliquant de multiples partie-prenantes aurait du sens, à la fois pour la gestion de ces déchets et pour le développement de l'agriculture périurbaine. Au-delà des boues et des déchets verts, il existe une large gamme de déchets urbains potentiellement utilisables en agriculture et dont le recyclage est de plus en plus incité, comme les déchets alimentaires des cantines. Il est important de disposer d'experts consultants en charge d'aider à la communication avec les agriculteurs et avec les habitants..

6. Conclusions

L'approche intégrée des SES et de la MFA appliquée à l'agriculture périurbaine a permis de distinguer quatre catégories de relations, qui caractérisent les contributions des agriculteurs au maintien de nombreux SES de régulation et de support, au-delà du SES d'approvisionnement, dans les agro-écosystèmes et dans les espaces naturels aux alentours.

L'étude détaillée menée sur la gestion des friches a identifié que l'abandon massif dans les zones urbaines était particulièrement liée au cours des trois dernières décennies, au développement des Villes nouvelles et de l'aéroport Charles de Gaulle. Dans les zones plus rurales, cet abandon est surtout lié à des questions agronomiques. Les perceptions des acteurs locaux quant aux services et dis-services portés par ces friches diffèrent selon l'aire géographique et l'échelle. Les acteurs ont aujourd'hui une préférence pour une utilisation de ces friches dans une stratégie de multifonctionnalité de l'agriculture.

La seconde étude détaillée montre que la production des boues de station d'épuration ne coïncide pas avec la distribution des terres susceptibles de les accueillir. L'épandage des boues de fait se déplace des zones périurbaines vers l'ouest de la région ile de France et ses abords. Au contraire, les composts de déchets verts deviennent de plus en plus populaires dans le monde agricole. Notre étude a permis d'analyser les relations offre-demande à plusieurs échelles et permis d'identifier sept catégories d'agriculteurs concernant l'attitude vis–à-vis des déchets urbains.

L'utilisation de ce cadre intégré SES/MFA et l'approche multi scalaire seraient intéressante à utiliser dans d'autres cas d'étude. Des comparaisons entre pays sur leurs agricultures périurbaines seraient aussi importantes pour comprendre les points communs et différences dans la hiérarchie des fonctions et des services et pour élaborer des instruments efficaces pour préserver cette agriculture périurbaine souvent menacée.