Acronyme / Acronym	PEERLESS		
Titre du projet	Viabilité d'une gestion écologique renforcée de la santé des plantes dans les paysages agricoles		
Proposal title	Predictive Ecological Engineering for Landscape Ecosystem Services and Sustainability		
Axe(s) thématique(s) / theme(s) *Ou* **Projet pluridisciplinaire / multidisciplinary proposal**	☐ 1 X 2 ☐ 3 ☐ 4 X 5 ☐ 6 X OUI ☐ NON		
Type de recherche / Type of research	X Recherche Fondamentale / Basic Research ☐ Recherche Industrielle / Industrial Research ☐ Développement Expérimental : Experimental Development		
Coopération internationale (si applicable) / International cooperation (if applicable)	Le projet propose une coopération internationale / International cooperation with : ☐ avec un ou des pays spécifiquement mentionnés dans l'appel à projets / countries explicitly cited in the call for proposal ☐ autres pays / other countries		
Aide totale demandée / Grant requested	807 k€	**Durée du projet / Projet duration**	48 mois

1. EXECUTIVE SUMMARY

With the shift towards a reduced reliance on external inputs in agriculture, identifying management options that enhance the provision of ecosystem services has become a critical issue. Pest control resulting from the activity of naturally present predators and parasitoids is frequently cited as an important service that could reduce pesticide use as targeted by the French 2018 Ecophyto governmental action. However, the link between management options, pest control level and ultimately crop yield is poorly understood. The *PEERLESS* project aims to identify alternative management strategies that enhance the crop protection service provided by functional biodiversity and ultimately to optimize agricultural systems, at local and landscape scales, for economic viability and sustainability. *PEERLESS* brings together six partners organisations with extensive expertise in agronomy, spatial ecology, ecology of interactions and public economy. The project combines: (i) an empirical assessment of naturally occurring crop protection from weed and insects pests in annual (Wheat/OilSeed Rape [W/OSR] rotations,) and perennial (apple orchards) systems across a broad range of landscape and agronomic situations; (ii) ecological engineering with an assessment of alternative plant protection system to improve crop protection at the local scale; (iii) an in-depth study of the structure of trophic networks; and, (iv) population dynamics of key pests and their regulators in case study areas. These components will support the parametrisation of spatially-explicit, predictive models to (v) test the effect of landscape patterns of alternative local and landscape management strategies on pesticide use, pest control, crop yield and farmer income and (vi) identify landscape scale viable management strategies to control insect and weed pests.

2. CONTEXT, POSITION AND OBJECTIVES OF THE PROPOSAL

2.1. CONTEXT, SOCIAL AND ECONOMIC ISSUES

Humanity faces unprecedented challenges arising from the scale of human activity and its impacts (Millennium Ecosystem Assessment 2005). Human actions are important drivers of global change, including changes in land use and biogeochemical cycling, emergent diseases, invasive species, biodiversity loss and climate that could irreversibly affect the well-being of current and future generations. Predicting the trajectory of global change and human well-being requires an integrated analysis of the dynamics of social–ecological systems (Polasky et al 2011). Agriculture is one important driver of this global change and among the most serious threats to biodiversity (Krebs et al. 1999; Tylianakis et al 2008). Large-scale modern farming has seen great increases in nutrient and pesticide uses and the simplification of the agro-system by reduction and fragmentation of semi-natural habitats to support agricultural profitability. Higher intensity of land use has also led to conflicts between crop production and other ecosystem service provision in what had been described as ''the tragedy of the commons'' (Hardin 1968): example tensions include water surface pollution, the evolution of pesticide resistance, and loss of biodiversity and of linked ecosystem services (Devine & Furlong 2007; Krebs et al 1999). Pressure on limited resources due to human population growth poses a critical challenge to the maintenance of sustainable food supply with a minimal loss of biodiversity. Such a 'perfect storm'[1] of challenges requires that we change our global paradigm of pure intensification to one based on landscape sustainable development (Rifkin 2011), through maximising the benefits of ecosystem services provided by farmland biodiversity, such as the control of pest populations by predators and parasitoids (Bianchi et al. 2006) supported by 'ecoagriculture' landscape management (Scherr & McNeely 2008; Kareiva et al 2011).

National- and European-level public policies currently promote alternative methods of crop protection, notably based on pesticide reduction and ecological services. The reform of the Common Agricultural Policy (CAP) in 2013 is likely to lead to the 'greening' of direct payments. The distribution of direct payments will be more closely linked to environmental-friendly ways of farming. It is currently a matter of some debate whether each farm enterprise should have to dedicate a minimum percentage of their farmland area (5-10%) to semi-natural habitats in order to be eligible for any direct payments. Parallel regulation for plant protection products (EC 1107/2009 and directive 2009/128/EC) establish a new framework to "achieve a sustainable use of pesticides by promoting the use of integrated pest management and of alternative approaches including the utilization of ecological infrastructures inside and outside production sites". Overlying these European directives, the French law "Grenelle de l'environnement" defined the "Ecophyto 2018" goal to reduce pesticide use to 50% of the 2008 level within 10 years (Butault et al 2010).

This framework of legislation has created an urgent requirement for landscape engineering methods. How should our agricultural landscapes, containing both crop and semi-natural habitats, be structured and plant protection products and pest management be employed within them to maximize ecosystem service provision?

2.2. POSITION OF THE PROJECT

The *PEERLESS* proposal fits axis 2 of the ANR Agrobiosphere call for the "elaboration of alternative strategies to face global change" and axis 5 dedicated to "alternative plant protection management". The project will focus on the functional biodiversity that supports crop protection ecosystem services against important agricultural pests. *PEERLESS* will elaborate predictive, integrated strategies of crop management at both local- and landscape-scales in both perennial (apple) and annual (W/OSR rotation crop) cropping systems to reflect the scales of policymaking and the diversity of agricultural landscapes across the France.

[1] Global crisis 'to strike by 2030' http://news.bbc.co.uk/2/hi/uk_news/7951838.stm

PEERLESS builds upon the results and uses the tools from several French national scientific projects to evaluate, support and forecast changes in biodiversity in agricultural landscapes (some projects included the participation of many of the *PEERLESS* partners and are detailed in **App. 8-1**). These projects have established that biodiversity in different cropping systems and agricultural landscapes is correlated to agronomic and landscape factors (Ecco des vergers, BiodivAgriM, Advherb, Landscaphid). The projects have produced molecular tools to identify: i) the taxonomic components of this biodiversity in agrosystem; ii) interactions between selected insect pests and their parasitoids; and, iii) pest population dynamics (Ecco des vergers, Landscaphid). Parallel projects have developed methods to design and evaluate cropping systems (Gédupic, Picleg, Advherb, EXPE-Ecophyto) based on environmental, agronomic and socio-economic criteria and including the landscape dimension (DynRurABio, Advherb, BiodivAgriM).
PEERLESS is also complementary to the work of European and international teams working to develop the design of agricultural landscapes to enhance agro-ecosystem services. The work of Miguel Altieri (Universities of Berkley), Yvette Perfecto (U. of Michigan), Steve Polasky (U. of Minnesota), Yves Carrière (U. of Texas), Steven Wratten and Jason Tylianakis in New Zealand and Teja Tscharntke and Carsen Thies' group at Göttingen University in Germany has been instrumental in the formation of this project. We believe that the development of *PEERLESS* will be greatly enhanced by the contacts we have with these groups. The work in *PEERLESS* will also feed into, and benefit from, several ongoing and finished European projects on innovation in crop protection practices (e.g. PURE[2], coord. by F. Lescouret at PSH) and sustainable land use (e.g. SENSOR)[3].
This national and international research context has highlighted clear gaps in current agricultural research that *PEERLESS* explicitly aims to fill. There is a clear lack of comparison between perennial systems with annual crops, which have been more widely studied. It is also apparent that knowledge of ecological processes, particularly in relation to spatio-temporal heterogeneity in agronomic practices, is sparse. The designs of the agricultural landscape mosaics remains extremely simplistic (usually contrasting organic *vs* conventional farming) and does not take into account the diversity of crop practices nor the interactions among crops and between the crop and semi-natural habitat. The work also underscores how important it is to develop predictive simulation models for the complex of scenarios (ANR 'blanc' EMILE) and to parameterise these models with realistic values for ecological processes and regional variation (BiodivAgriM, SENSOR). Such parameterisation requires that *PEERLESS* adopts integrated multi-disciplinary approaches.
To achieve the goals we have set, the *PEERLESS* project will deliver decision-support knowledge for landscaping and ecological engineering, which will be validated through experimental testing in case study landscapes (25-100 km^2 in apple and cereal production systems that are already part of long-term monitoring). Predictive scenarios will be elaborated through simulations of ecological processes at the field and landscape levels and

[2] PURE (2011-2015) : Innovative crop protection for sustainable agriculture (coord. by F Lescouret, PSH partner).
[3] SENSOR (2004-2009): Sustainability Impact Assessment: Tools for Environmental, Social and Economic Effects of Multifunctional Land Use in European Regions

will be evaluated using environmental, agronomic and economic criteria. These simulation models will require evaluating crop practices and their evolution, and understanding ecological mechanisms linked with the ecosystem services of biocontrol before building and optimizing the models. In **App. 8-3** we detail our justification of the hierarchy of relationships between agronomical practices and the biodiversity of insect and weed pests and putative beneficials in apple orchards and W/OSR rotations that the *PEERLESS* project will consider.

2.3. STATE OF THE ART

2.3.1 Relation between floristic biodiversity and pest control

Over the last 15 years, non-crop habitats (seminatural habitats) have attracted the attention of ecologists and land managers as "green veins" of biodiversity running between arable fields (Billeter et al. 2008). Studies have demonstrated a positive relationship between the amount of such habitats and the abundance of predators that may regulate crop pests (Bianchi et al. 2006). Effects have been explained by seminatural vegetation offering hibernation refuges (ground beetles), nectar and pollen resources (parasitic wasps, hoverflies) and alternative food when crops and pests are absent (Landis et al. 2000, Den Belder et al. 2002, Thies et al. 2003). This functional relationship between predators and non-crop vegetation would suggest a strong interplay between plant functional traits and species composition on ecosystem service provision, but this influence has rarely been directly tested. A better mechanistic understanding of floristic composition effects on crop herbivory is crucial for management decisions to improve ecosystem services.

Despite gaps in our mechanistic understanding, "wild flower strips" have been developed and implemented in agri-environment schemes of several European countries (Haaland et al. 2011; Bischoff et al. 2010). The approach has rarely been focussed on the control of crop pests, directly, but on an increase of plant, insect and bird biodiversity (Heitzmann 1994, Marshall & Moonen 2002, Vickery et al. 2002) or on the abundance of potentially beneficial insects (Nentwig 1989, Frei & Manhart 1992, Legrand & Roy 2007). The choice of service plants is based on observation or screening (Frei & Manhart 1992) or plant traits (e.g. floral and extrafloral nectar) that could favour beneficial insects (Geneau et al. 2012). However, the increases in "beneficial" predators does not necessarily reduce crop herbivory and naturally-occurring vegetation may be more efficient in suppressing crop herbivory than wild flower strips designed to favour beneficial predator groups (Denys & Tscharntke 2001). Studies demonstrating a suppression of crop herbivores by manipulation of field margin vegetation are still rare (Pfiffner et al. 2003; Veres et al. 2011). In order to optimise "wild flower strip" that increase predator and parasitoid densities and reduce crop damage, plant species and/or mixtures have to be identified and designed in agreement with the agronomic practices. It has also to be proven that these mixtures are more efficient than natural vegetation in field margins.

2.3.2 Relation between inter-specific animal biodiversity and pest control

The "species complementarity model" of biodiversity predicts positive relationship between inter-specific biodiversity and suppression of pests if there are synergistic effects among natural enemy species. This relationship may however be flat or even negative in case of negative interactions among species such as behavioural interference, or hyper-parasitism (Rosenheim 2007, Schmitz 2007). The "sampling effect model", in contrast, predicts that diversity may be positively correlated to pest suppression simply through the increase of the probability of picking an effective natural enemy (Myers et al 1989, Perfecto et al 2004, Stireman et al 2005). In their review, Letourneau et al (2009) report that in agricultural systems there is a significant general trend for natural enemy species diversity to increase pest suppression but that there is also high variation. One explanation for this variation is that taxonomic or functional diversity are only two of many ways of measuring diversity and may not be appropriate variates. Rather, complementary approaches based on species traits (Tylianakis & Como 2010) and food web characteristics (Tylianakis et al 2008a) might have greater explanatory power. This work points to the key role of intraguild predators (Ingels & De Clerc 2011) and hyper-parasitoids (Traugott et al 2008) and globally, the complexity of food web structure (Montoya et al 2003) for controlling herbivore pests.

2.3.3 Species interaction in crop field

Ecosystems are structured by flows of energy between primary producer plants and consumers (Lindeman 1942; Dickinson & Murphy 1998). Networks of trophic links (food webs) are therefore very important for explaining ecosystem structure, robustness and dynamics (Odum 1971; Caron-Lormier et al. 2009; Cohen et al. 2009). Understanding the relationships between species interactions and the robustness of interaction networks to species loss is essential to predict the effects of declines and extinctions. In a recent *Science* paper, Pocock et al. (2012) examined multiple component networks of the same agroecosystem. Importantly, they found that the different networks did not strongly covary in robustness. This would indicate that methods for ecological restoration of particular parts of agroecosystems (for example, through agri-environment schemes) or augmenting distinct ecosystem services will not necessarily boost other parts of the ecosystem. As the authors state "The optimist's scenario, of management targeted to benefit one animal group and inevitably resulting in multiple benefits for many different groups, was not supported by our modeling of empirical species' interaction data".

Pocock et al. (2012) illustrate the potential power of food web-type approaches for establishing ecologically-driven management advice for ecosystems and sustainable intensification. However, the work also shows the clear gaps in our current understanding. Firstly, networks often ignore generalists and omnivores that could switch between different component networks (Bohan et al. 2011b), potentially linking networks together and modifying our expectations. These groups make up the greater part of the invertebrates in agroecosystems, and have received considerable research efforts as providers of ecosystem services (Bohan et al. 2011a, Symondson et al. 2002). Yet, these groups are poorly studied within networks because of difficulties of evaluating the spatio-temporally dependent links that they make. Secondly, current approaches lack generality. Methods for comparison between networks or between agroecosystems by constructing and validating networks based upon species functionality that supports ecosystems services still remain to be developed. Finally, the large scale, primary ecosystem services of agriculture, such as crop yield or productivity, are rarely included within current network approaches. In *PEERLESS*, it is our aim to tackle these problems by explicitly developing cross-discipline approaches to build and test networks that include the generalist/omnivores, which can be tested for generality – by reflecting functionality – and which allow trade-offs to the productive, primary ecosystem services of agriculture.

2.3.4 Population dynamics in agricultural landscapes

Understanding the population dynamics of species that trophically interact will be another *PEERLESS* aim. At the landscape scale, patch isolation and size are predicted to negatively affect population density and species richness (Hanski & Gilpin 1991; Conor et al 2000). Patch quality has positive effects on population density (Thomas et al 2001). These three variates differentially affect specialist and generalist species (Krauss et al 2003) and groups at different trophic levels in the food web (Anton et al 2007). Consequently, landscape structure can have a marked effect on population density of both pests and natural enemies (Kruess & Tscharntke 1994). However, the analysis of landscape pattern on the distribution and dynamics of pests is less developed than for species of conservation value. The two types of species differ in terms of adaptation to agricultural environment (e.g. their capacity to use ephemeral habitats) and movement. What constitutes a corridor for species of conservation value (semi-natural habitat) may be a barrier for pests. Identifying this barrier for pest and corridor for their natural enemies can be a very attractive way to enhance pest control (Keitt et al 1997). Genetic studies at large scales have revealed a low genetic structuring of pest populations at continental scales (e.g. Franck et al 2007; Guillemaud et al 2011), suggesting that dispersal behavior is weakly influenced by landscape structure. However, studies carried out at the landscape scale indicate a strong landscape effect on dispersal (Franck et al 2011). This inconsistency may result from dispersal behavior depending on life cycle. By example, aphids disperse over large distances in spring and autumn, during host alternation, but adopt local dispersal within the season. Hence, landscape structure may poorly influence the primary colonization process but impact the local secondary spread. Crop protection practices across the landscape can be detrimental for both pest and natural enemies and are a major determinant of local adaptation. Such practices affect population abundance at larger spatial scales (Carrière et al 2006; Ricci et al 2009), and emphasise the importance of integrating local and landscape scales and jointly considering pest and natural enemy dynamics to enhance pest control (Cronin & Reeve 2007).

2.3.5. Managing sustainable agricultural landscapes

There are two important economic dimensions to consider when discussing the pros and cons of alternative land use to control insect and weed pests.

First, form a macro-economic point of view, better environmental or ecological outcomes may be associated with lower economic outcomes. There may be trade-offs between the different dimensions of sustainability in agriculture. Such trade-offs at the regional or landscape levels have been examined in Polasky et al. (2005, 2008, 2011). By means of modeling and selection of optimal land uses, a production possibility frontier of biodiversity and economic profit is constructed by maximizing an outcome under a constraint on the other (e.g., maximizing the economics outcome under an ecological outcome constraint). By varying the level of the ecological constraint, one obtains a set of feasible productions – in a broad sense, including economic and ecological dimensions – whose frontier is usually decreasing. Society has to arbitrate between the two objectives on the (Pareto) efficiency frontier, where it is not possible to improve one outcome without reducing the other. It is, however, important to emphasize that current land uses may be far from efficiency, within the set of possible production situation. Adopting eco-efficient practices may then result in an increased economic outcome ("win-win" situation).

Second, from a micro-economic point of view, it is necessary to assess the cost of improving the agricultural practices from an ecological point of view. This cost is related to the socio-economic acceptance of the alternative practices, and the economic viability of the underlying production patterns. Usually, landscapes are the result of the interaction of numerous individual decisions by private land owners. In such a context, implementing a given land-use pattern is made difficult for two reasons. On the one hand, one has to define proper incentives to modify the individual behaviors in favor of the desired land uses. As the agents are usually heterogeneous and the decision maker does not know their Willingness To Accept (WTA – the amount required to adopt the practice), such policy instrument may be costly as many farmers may be over-paid (Jack et al 2008). On the other hand, the spatial effect of the incentives has to be consistent with the spatial pattern of the ecological objectives. This requires developing "smart spatial incentives" (Hartig & Dreschler, 2009). If the desired ecological pattern to conserve is expected to last over time, it is of crucial importance to also investigate the sensitivity of economic models to the choice of the time horizon or time preference (Hartig & Drechsler 2008).

The evaluation of various scenarios of agricultural land use in *PEERLESS* will be based on interdisciplinary modeling, encompassing agronomic, ecological and economic features.

2.4. OBJECTIVES, ORIGINALITY AND NOVELTY OF THE PROJECT

The *PEERLESS* project has the ambition to propose landscape management of an important environmental service for the agricultural purpose: the **biocontrol** of insect and weed pests by their natural enemies in contrasting perennial and annual cropping systems (**apple orchards** and **wheat/oilseed rape rotations**). The *PEERLESS* project will evaluate biocontrol service based on ecological, agronomical and economical criteria in order to **optimize sustainable cropping systems** and to **design landscape mosaics** that are viable for farmers and in agreement with public policies. It has the ambition to design scenarios of landscape management that could be progressively implemented to achieve purposes of the national ECOPHYTO action.

To complete this project, *PEERLESS* will integrate: (1) different **spatial and temporal levels** to understand interactions between field and landscape for a global evaluation of the impacts of crop management; (2) several ecological disciplines and spatial statistics to understand **ecological mechanisms** involved in **inter-specific interactions** and **population dynamics** and (3) ecological, agronomical and economical data using **engineering sciences** and modelling to propose alternative crop systems and **viable landscape design**.

More especially, the project will follow three objectives, which are the *PEERLESS* pillars:

1-Identify farming systems and landscape pattern in which functional biodiversity enhances crop productivity through improved provision of ecosystem services of biocontrol. The investigated cropping systems and landscapes will reflect climatic and environmental gradients in France. We will achieve this purpose by surveying a large number of commercial and experimental farm fields with their associated semi-natural habitats and by rigorous statistical analysis of existing large-scale data sets available within the consortium.

2-Identify ecological mechanisms linked with spatio-temporal heterogeneities in densities of agronomic pests and their natural enemies that enhance ecosystem services of biocontrol**.** We will establish the fundamental agronomic and ecological interactions between functional biodiversity in annual crops and perennial orchards, semi-natural habitats and crop productivity at practical and policy-relevant spatial and temporal scales. This mechanistic and process-based study will be performed across situations contrasted in semi-natural habitat quality and quantity and farming systems intensity to fill critical knowledge gaps in the understanding of food web structure and population dynamics needed for successful biocontrol services delivery.

3-Design viable deployments of alternative crop system and semi-natural habitats in spatially explicit landscapes that are sustainable for farmers and in agreement with public policies**.** We will establish landscape scenario based on simulation models of populations dynamic of both pests and their enemies that optimize crop productivity, pest control, pesticide reduction and farmer incomes.

3. SCIENTIFIC AND TECHNICAL PROGRAMME, PROJECT ORGANISATION

3.1. SCIENTIFIC PROGRAMME, PROJECT STRUCTURE

The *PEERLESS* project will be divided in six scientific tasks - two different tasks for each of the above three pillar objectives – and a seventh task for management and valorization (Fig 1). Collections of ecological, agronomical and economical data will be realized in the project at several long-term monitoring agricultural landscapes and on experimental crop systems (Apple orchard and W/OSR rotation, Fig 2). A representive for each site will be defined by each *PEERLESS* partner. These representatives will define together identical protocol to monitor common pests and few of their natural enemies (Annexe. Furthermore, a common synthetic data base will be managed at Dijon by the AE partner to unsure the comparison among sites. This SIG database will also compile previous data important for the *PEERLESS* project, which will be exported from existing database in each partner.

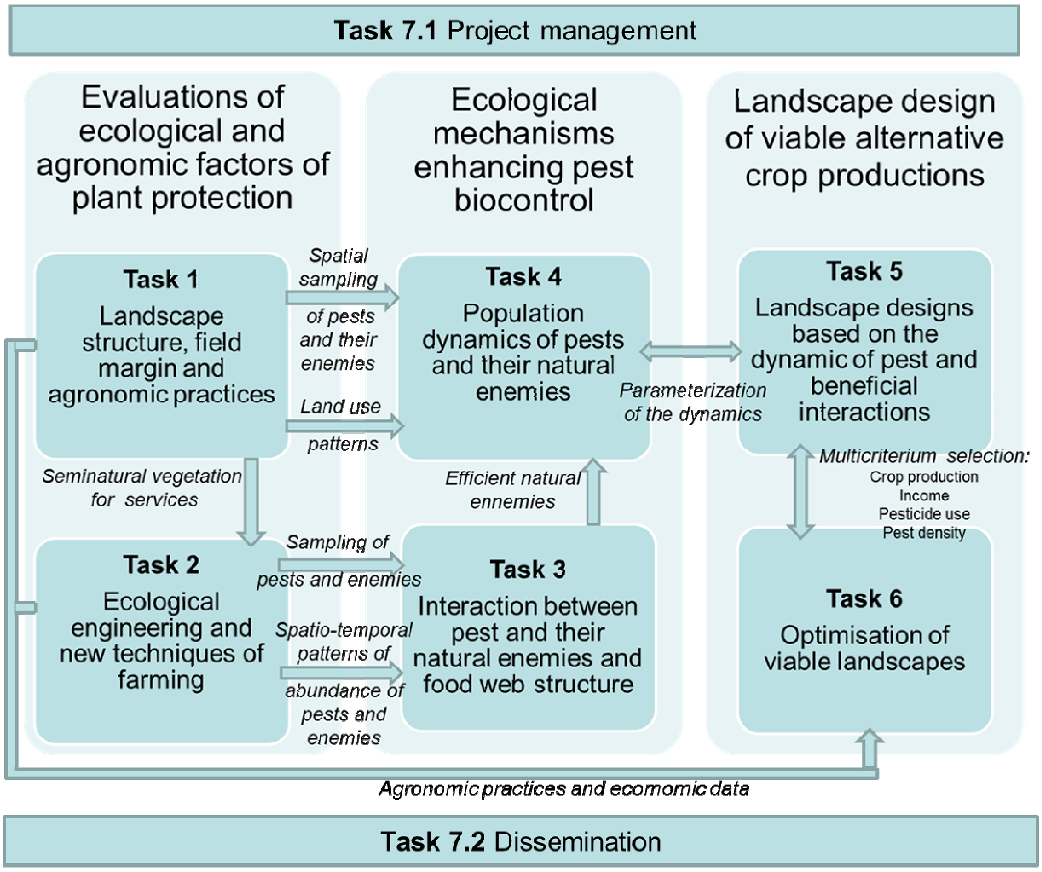

Figure 1 : Schematic representation of information flow between tasks within *PEERLESS*

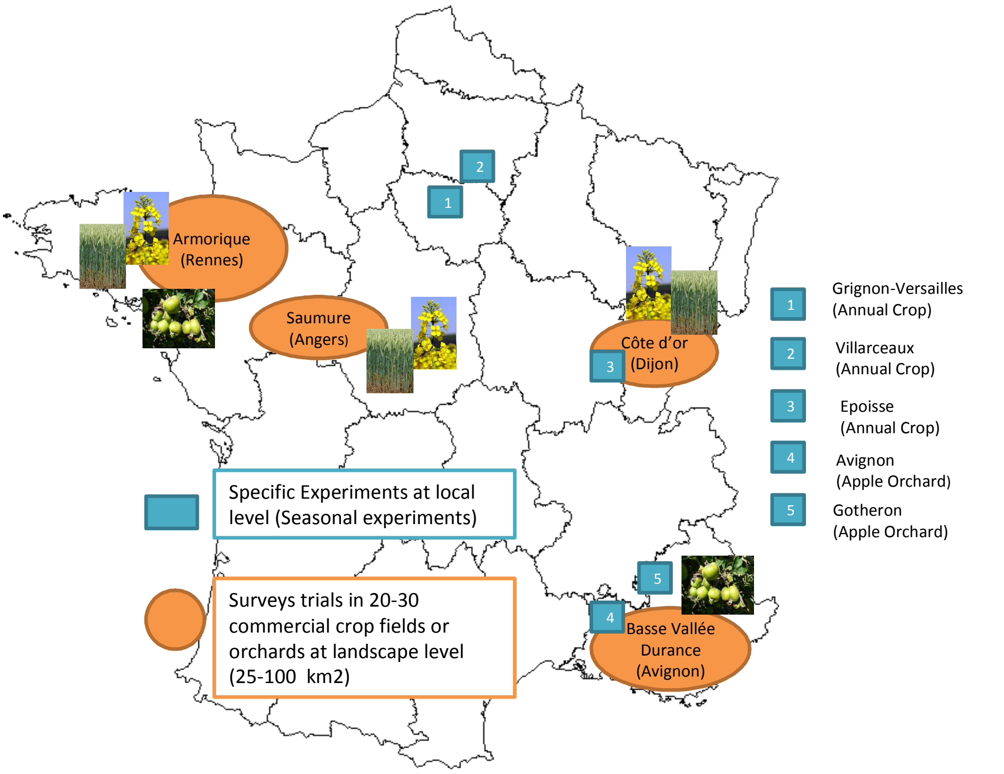

Figure 2 : Location on a map of France of landscape areas where field surveys will be performed in task 1 (orange) and of experimental sites (blue) that will be used for specific experiments in tasks 2, 3 and 4.

3.2. Management du projet / Project management

Each scientific task will be co-coordinated by two leaders from a different partner in the consortium. Task 7 will unsure the management, the exchange of data among the scientific tasks 1-6 and dissemination of *PEERLESS* results. Daily monitoring of the project will be ensured by the coordinator. Furthermore, the 12 coordinator of the scientific task will form an executive comity to unsure *PEERLESS* progress and prepare ANR reports. They will meet them three times each year (subtask 7-1). Annual meeting on two consecutive days will be organized with all the participants by a different partner each year. It will invite external technical advisors to promote dissemination of *PEERLESS* results. Finally, although each scientific task will produce their own set of results, they will be mostly the results of the *PEERLESS* collaboration. Strategies of valorization, notably for publications, will be defined by the executive comity (subtask 7-2).

3.3. Description by task

3.3.1 Task 1: Evaluation of landscape structure, Field margin and in-field agronomic practice on plant protection

Resp.: Sandrine Petit (AE) & Claire Lavigne (PSH**)**
Contributions: AE, IGEPP, PSH
Objectives

- ✓ Assessing the relative contribution of local and landscape management options on pest abundance, pest control and crop damage/yield
- ✓ Ranking combinations of local and landscape plant protection systems in terms of pest control efficiency, analysing potential trade-off (practices in the field, including pesticide pressure, field margins, landscape context).
- ✓ Setting up a database allowing the population dynamic studies in task 4 and the multicriteria evaluation of these combinations in task 6

Program and Methods

Identifying management options enhancing the provision of pest control services has become a critical issue. There is a general consensus that such options should not only target individual fields but should also often encompass larger spatial areas that are relevant for organisms involved in the delivery of services (Landis et al 2000; Tscharnke 2005). A number of studies have successful assessed the effect of local (in-field and field margins) and landscape factors on the diversity and abundance of natural enemies (see meta-analyses from Letourneau 2009; Chapin et al 2011; Veres et al 2011), although local and landscape factors are often dealt with in separate studies rather than in parallel. Yet, the contribution of local and landscape factors to pest abundance and to the level of biological control has proved more challenging to assess and has led to inconsistent findings (Chapin et al 2011; Veres et al, 2011; Thies & Tscharnke, 1999; Bianchi et al 2006). There is surprisingly even less studies relating local and landscape management options to crop damage or yield (Thies et al 2003; 2008) and again, what is known is equivocal (Bianchi et al 2006). The novel aspect of Task 1 is to explore the effect of management at multiple scales on pest abundance, crop damage and ultimately crop yield and farmer's income (see Task 6). There is indeed a need for Task 1 to estimate the 'avoided crop damage' due to local and landscape management options in order to provide data to '*optimize the effect of alternative plant protection systems on pest control*' in later Tasks of this project. This estimation will be carried out empirically and based on the collation of data previously collected by the different partners as well as on the collection of additional in-field measurements. The effect of alternative plant protection systems on pest control will be analysed simultaneously at three spatial management scales, namely (i) field or orchard where TFI and soil tillage regime will vary, (ii) the field margin area which acreage, management type and vegetation composition will vary and (iii) the landscape level which will vary in terms of composition, structure and overall management (e.g. proportion of organic production).

Sub-task 1.1: Setting up a 'pest control' landscape database

Several teams of this consortium have collected abundance data on pests and natural enemies at the landscape level in previous funded projects (annual crops: ANR Systerra Landscaphid on aphids and their parasitoids and predators, ANR Systerra Advherb on weeds and associated granivorous predators; perennial crops: ECOGER EcoVerger and ADD Gedupic on codling moth and their parasitoids and predators). Regions under focus within this project are for annual crops the ZA 'Armorique' and the site atelier 'Côte d'Or' and for perennial crops again the ZA 'Armorique' and the 'Vergers de la Basse Vallée de la Durance' (Fig. 2). Landscape variables, in-field agricultural practices and crop yield have been described with varying levels of detail in the different studied landscapes and the available set of sites clearly encompasses a large spectrum of landscape and agronomic situations. In these landscape zones, pest control has also been estimated through the set-up of sentinel organisms (seed weed cards, codling moth egg cards) in a large number of sites. Sub-task 1.1 will be devoted to the collation and analysis of existing data in order to (i) characterise the range of situations covered in terms of FTI and soil tillage practices, field margin structure and landscape properties (ii) identify landscape and agronomic situations where additional survey is needed for crop damage/yield estimates and/or agronomic practices (see sub-task 1.2) and (iii) collect socio-economic data where all other data is already available (Task 6).

Sub-task 1.2: Local and landscape management and crop damage/yield

The aim of task 1.2 is to explore the relationship between management options at multiple scales and crop damage/yield. To reach a sufficient number of sites for statistical analyses, the dataset collated in task 2.1 will be extended by carrying out additional surveys within the existing 3 landscape zones and an additional ('Saumur') zone using standard protocols. The protocols will include an analysis of landscape features, field margin vegetation and land use intensity as explanatory variables. In annual systems, we will estimate weed, aphid and pollen beetle abundance together with crop damage/yield in 20 fields for each of three landscape zones (Armorique, Cote d'Or and Angers/Saumur) as response variables. In perennial systems, we plan to include codling moth abundance and fruit damage in 20 new orchard sites located within the ZA Armorique and in 20 orchards that were already surveyed in preceding projects in Vergers de la Basse Vallée de la Durance. The data collected will be added in the database developed within task 1.1 and the complete database used for analyses in sub-task 1.3.

Sub-task 1.3: Interpreting size-effect

This task aims at carrying out a generic and standard analysis of the relationship between local/landscape management options and crop production using the database developed in sub-task 1.1 and 1.2, using linear or generalized Mixed-Models multimodel inference when appropriate. As additional information is available from sub-task 1.1 on the abundance of natural enemies and pest control rates for some landscape and agronomic situations in the landscape zones, it will be included in order to interpret observed patterns (interpretation of size effects). The analysis will enable to rank combinations of local and landscape plant protection systems in terms of pest control efficiency as well as to identify potential trade-off between management options carried out at the three spatial scales.

Risks and solutions

The participating teams have experience working with farmers in commercial fields/orchards and sampling/ collecting information on farmers practices is not seen as a problem. It is possible that despite our efforts to avoid this, some landscape and local protection systems will covary to some extent because of neighbourhood effects. Multimodel inference can, to some extent account for these effects. If co-variation is too large, we will move towards hierarchical modelling.

Deliverables

- ✓ A 'pest control' landscape database compiling both existing (D1.1) and new data (D1.2).
- ✓ Scientific communication on the elative contributions of management options at crop and landscape levels to pest control with task 4 (D1-3).

3.3.2 TASK 2: ECOLOGICAL ENGINEERING AND NEW TECHNIQUES OF FARMING AND PLANT PROTECTION

Resp.: Armin Bischoff (IGEPP) & Muriel Morison (Agronomie)

Contributions: AE, Agronomie, IGEPP, PSH

Objectives

- ✓ Evaluating the pest control service of sown wildflower strips (monospecific and mixtures)
- ✓ Testing the effect of alternative crop management systems on the control of insect and weed pests
- ✓ Analysing the combined effects of vegetation and crop management on these ecosystem services

Task 2 is closely related to task 1 and will use the same target pest organisms. However, the focus will be on specific methods to improve ecosystem services at a local scale. The tests will be set up in different landscapes to evaluate the robustness of desired effects under different environmental conditions. Task 2 is also linked to task 3, 4 and 5. In a subset of task 2 experiments, the effect of ecological engineering on food web structure (task 3) and on pest population dynamics (task 4) will be analysed. The data of task 2 will be included in the models of task 5 to reduce pesticide and energy use.

Program and Methods

Sub-task 2-1 Management of non-crop habitats: the wildflower strip approach

Several tests have demonstrated that specifically designed species mixtures sown in wildflower strips have a positive effect on beneficial arthropods that feed on pest insects (Sivinski et al 2011, Haaland et al 2011). However, studies showing a suppression of those herbivores and their damage are still rare (Pfiffner et al 2003, Geneau et al 2012). We will compare different mixtures of candidate plants identified from task 1 and from the literature, and we will take into account pest insect infestation and crop damage in order to optimize the approach.

Wildflower strips in field margins: Wildflower strips are usually sown at field boundaries to avoid a loss of crop area and to increase acceptance by farmers (Haaland 2011). Several studies have been started to adapt simplified wildflower strips to French agriculture (Legrand & Roy 2007, Lambion & Boisnard 2009) but a comparative analysis of appropriate species assemblages is still lacking. Instead, grass strips have been favoured by agri-environmental policy to protect water bodies against pesticide and fertilizer drift (Cordeau et al 2012). The aim of this subtask is to test a mixture of candidate species of the native vegetation identified in the correlative analysis of task 1 in terms of pest insect and weed control. The effect of this mixture will be compared with that of grass boundary strips and the existing spontaneous vegetation as a control. The mixtures will be sown into the margins of arable fields in order to test their effect on crop herbivores, their natural enemies and weed infestation. These margin treatments will be replicated in different regions (Angers, Dijon, Grignon/Versailles), ideally in 5 fields per region. Grignon and Versailles represent two test sites of the same region but in different landscapes with 3 replicate fields per site. The experiments will focus on a crop rotation with oilseed rape and wheat. Target pest insects of the analyses will be cereal aphids, *Meligethes aeneus* and stem weevils (oil seed rape). The analysis of natural enemies will include predator and parasitoid groups that depend on nectar in a part of their life cycle (hoverflies, parasitic wasps). The effect on selected weed species will also be included in the analyses as wildflower strips may increase weed infestation on field edges. As a potential control agent of weeds, granivorous ground beetles will be recorded using pitfall traps. The identification of suppressive plant traits would allow to replace a problematic/unavailable species by a less problematic one showing the same functional traits. Using the results of task 1, two "candidate" functional groups will be tested in monospecific strips by varying the species within each functional group. Examples for potentially important functional traits are flowering period, entomophilous pollination or extrafloral nectar. The tests will be performed in the 'Angers-Saumur' zone using the same fields as in the mixture tests.

Non-crop vegetation within the fields: The positive effect of field margin vegetation on predator groups decreases with distance from the field boundaries. The sowing of wildflower strips into the fields has been proposed to facilitate their migration and to reduce this distance effect. This approach will be tested in two cases: silvoarable agroforestry and in orchards.

Agroforestry is an innovative system that is generally implemented with agronomical (resource complementarity between crop plants and trees) and economical (timber production) objectives. It also offers opportunities for conservation biological control, not only because of the presence of trees but also because the herbaceous strip in/out tree line can be sown with flowering plants and thus provide additional resources for natural enemies. The effect of the plant species sown will be tested in a split plot design (main plot: annual crop, subplot: strip composition (2 mixes of flowering plants, spontaneous vegetation) in organic crops. Target pest insects of the analyses will be aphids and the analysis of natural enemies will include predator and parasitoid groups that depend on nectar in a part of their life cycle (hoverflies, parasitic wasps). The tests will be performed at Villarceaux. In apple orchards, three treatments will be compared: (i) sowing of wildflower strips, (ii) spontaneous vegetation with the usual mowing regime (5 times a year) and (iii) spontaneous vegetation with reduced mowing (2 times a year). The wildflower strips will be monospecific (*Fagopyron esculentum* or *Phacelia tancetifolia*) and species choice will be based on experiments comparing the attractiveness for beneficial insects (in the framework of the PURE project in collaboration with S. Simon, Gotheron). The analyses will focus on apple aphids and codling moth. Ground beetle abundance, predation of codling moth eggs and parasitism by parasitic wasps will be recorded to evaluate effects of wildflower strips on natural enemies. The experiment combines the wildflower strip treatments with orchard netting as a direct protection method against insects (see subtask 2.2). Study sites are Avignon and Gotheron (Fig. 2).

Sub task 2-2 Management of crop habitats: Effect of alternative cropping systems

Many technical solutions have been developed for the management of crops with the objective of reducing either pesticides or fossil energy use while maintaining acceptable production levels (Mediene et al, 2010). These techniques have important effects on soil fauna that have rarely been studied. Since crop management is a coherent system, it makes sense from an agronomical perspective to study these innovative techniques inside their cropping system. As a consequence, techniques will not be compared in a factorial design but in a systemic approach comparing conventional, no-till, zero-pesticide and organic farming. We will focus on innovative techniques that affect biotic interactions either indirectly through habitat modification (soil tillage, cover crops) or by a direct effect on populations (pesticides, protective netting).

Modification of crop habitat: No-till systems are characterized by an increase in organic matter at the soil surface, because crop residues are not deeply buried in the soil. Several studies have shown that this accumulation of organic matter at the soil surface almost always leads to an increase in the diversity of generalist predators (ground beetles, spiders and rove beetles) (Hanna et al, 2003; Mathews et al, 2004; Schmidt et al, 2004; Pullaro et al, 2006), but the effect on the lower trophic levels (pests, plants) hasn't been fully characterised. Observations on long-term experiments set up in Versailles and Grignon will be used to compare the effects of conventional vs no-till systems on weed-pest regulations under the same pedo-climatic conditions but in different landscapes. Observations on this cropping systems experiments will focus on (1) the abundance of the same target pests, mentioned

before, (2) on the abundance of the same predator and parasitoids groups as in 2-1, using traps, (3) on the natural regulation efficiency (predation of pests and weeds, parasitism rate) and (4) on yield losses and pest damage. No-till systems may suffer from increased weed infestation resulting in higher herbicide use. A way to cope with this problem is to implement a relay or permanent cover crop (sowing a second crop when harvesting the main one), thus creating a living mulch that prevents weeds from germinating or thriving (Teasdale et al, 2007). The main goal of cover crops is to control weeds, by replacing an unmanageable weed population with a manageable cover crop. A further goal that could be assigned to the living mulch is creating a more favourable environment for natural enemies by increasing plant biodiversity, which would require a careful choice of associated plants. Different cover crops in no-till systems will be sown in a network of arable fields near Dijon, in order to analyse the impact of different cover crops on seed predation by granivourous carabids and on pest regulation.
Direct modification of pests' populations in the field: Low input systems are characterised by modifications of pest populations (abundance and diversity) in both annual crops and orchards due to a reduction in pesticide use. It can be expected that the abundance of natural enemies increase, but it is a challenge to obtain sufficient levels to improve pest regulation and to reduce the pest populations. The objective of this sub-task is to analyse and quantify the impact of low-input systems on pest abundance and natural regulation. For annual crops, we will test the impact of alternative systems, such as zero pesticides and organic systems, on the abundance of main pests attacking grain crops (see above for main pests) and the natural regulation efficiency (parasitism rate, weed-pest predation). For apple orchards at the avignon site, the low-input system is based on the use of insect-proof nets (named Alt'carpo) mainly designed to physically protect apple orchards from their main pest, the codling moth. We will test the interaction between flower strips and these nets (the mesh size allows parasitoids to enter, but nets may be impermeable for hoverflies). In Gotheron orchards, organic and conventional management will be compared in combination with wild flower strips (see subtask 2-1)

Risks and solutions

Plant species identified to have a suppressive effect on pest insects in task 1 may be undesired weed species or difficult to propagate. The identification of plant functional traits that improve pest control would allow a replacement by less problematic species showing the same trait characteristics.
It is also possible that the effect of the spontaneous field margin vegetation is not strong enough to identify plant species that improve pest control (task 1). The correlative study on the relation between plant species composition and control service will be accompanied by an analysis of the existing literature to identify candidate plant species.
Plant-insect interactions may change during plant succession and desired effects of wildflower strips on pest control services may not be stable. Large temporal fluctuations may also occur in the effects of alternative cropping systems. The long-term experiments involved in task 2 allow an analysis of these fluctuations in ecosystem services of ecological engineering.

Deliverables

- ✓ Recommendations to optimize the wildflower stip approach in combination with different alternative cropping systems (D2-1);
- ✓ Identification of plant species and functional traits that have the potential to improve pest control: link with task 3 (D2-2);
- ✓ Multicriteria evaluation of ecological engineering effects on weed and pest regulation: link with tasks 1, 5 & 6 (D2-3);

TASK 3: ANALYSES OF FOOD WEB STRUCTURE IN CONVENTIONAL AND ALTERNATIVE PLANT PROTECTION SYSTEMS

Resp.: Manuel Plantegenest (IGEPP) & Dave Bohan (AE)
Contributions: AE, IGEPP, PSH

Objectives

- ✓ Develop and combine tools to estimate pest control service
- ✓ Reconstruct quantitative food web networks of major insect and weed pests in conventional and alternatives plant protection systems and studying their change through the growing season
- ✓ Determine the optimal assemblage of natural enemies that allow efficient pest control based on their trophic interactions (direct and indirect) and identifying factors, especially floral diversity (taxonomic and functional) favourable to the improvement of pest-regulation services.

Program and Methods

In most studies, efficient natural control of pests has rarely been attained in the simplified landscapes provided by intensive agriculture. Consequently, the improvement of regulation services provided by the ecosystem requires the maintenance or the restoration of a certain degree of complexity in the landscape both in terms of structure and composition and in terms of biodiversity (Benton et al 2003; Macfadyen & Bohan 2010). However, although the link between environmental complexity and biodiversity seems rather obvious, the consequences for pest control are equivocal (Bianchi *et al* 2006). We hypothesise that this results from diversity *per se* (*i.e.* species richness) being a poor determinant of ecosystem properties (Gagic *et al* 2011), which are more strongly dependent on the underlying interaction network (Tylianakis *et al* 2007). Thus, it is necessary to develop efficient tools for the identification, description and analysis of interactions networks.

We propose to develop several complementary methodologies for interactions network analysis based on: 1) community dynamics analysis; and, 2) molecular analysis of trophic relationships and to apply them to our case studies. In this task, we aim to understand the effects of agronomic practice and floral diversity on trophic foodweb structure and its consequences for pest control, and so producing generic tools to address such questions.

Sub task 3-1 : Inferring interaction network from data analysis

Methods for 'learning' food webs from existing ecological data-sets, based on Abductive/Inductive logic programming, have recently been developed (Bohan et al 2011b;

Tamaddoni-Nezhad et al 2012). The generated trophic links should be thought of as hypotheses and will be tested in Sub task 3-2, below, using molecular-based approaches. The learning methodology will use available data (FarmScale Evaluations, Firbank et al 2003; Bohan et al 2005) and data gathered during Task 2. The learning approach will ask three complementary questions: 1) can we link the invertebrates and plants within agricultural systems to understand better the effects of trophic behavior, including generalists/omnivores; 2) can we simplify the network structure to functional descriptions that more closely ally to functionally-based ecosystem services (Raybould et al 2011); and, 3) can we include primary plant productivity in the networks?

A second approach (currently being developed by UMRs IGEPP and Ecobio Rennes) designed to capture the main structure of the interaction networks from diachronic data, and will be applied to the set of data provided by the survey carried out in task 1. This method, based on generalized Lotka-Volterra modeling, is aimed at identifying the prominent structure of any interaction network from the dynamical properties of the system.

Results brought by the two approaches will be compared. A way to combine them efficiently will be looked for in order to enhance the reliability of the network inference.

Sub task 3-2 : Describing trophic network using molecular and more classical tools

Although correlative and dynamic analyses are of great interest in network identification and quantification they should be treated a generating hypotheses (correlation is not causality). Hence, biological verification is always required. Until recently, the study of interaction networks was hindered by the extreme difficulty to access to numerous and reliable data directly from nature. However, several powerful technological tools have been recently developed (environmental genomics, metagenomics) that can be added to older ones (stable isotopes analyses, pollen analyses) to provide a detailed description of trophic networks. We propose here to combine those various tools to provide the required biological confirmation to correlation analyses.

The purpose of this task will be to further perfect, compare and combine those various approaches that also differ in their resolutive ability.

- The first approach will rely on the analysis of stable isotopic ratios. This analysis will allow positioning all species in the food web and identifying sources of energy it uses. Mixing models will be used to infer the global structure of trophic network.
- The second approach will benefit from the development of next generation sequencing tools. High throughput sequencing of PCR products obtained using a combination of complementary primers will be used to identify preys consumed from the detection of their DNA in the gut or in the faeces of studied predators.
- The third approach will be based on pollen identification inside the gut of polliniphagous species.

The various approaches will be carried out simultaneously in some cases on the same individuals in order to be able to compare the networks inferred and their consistency. We assume that the various approaches differ in their precision (from the origin of the energy used and the trophic position to a precise description of the diet of an individual) but also

from their level of temporal integration (from the content of the last meal to the lifetime global trophic position).
The various tools will be applied to the description of trophic food webs implying main natural enemies of pests. The targeted groups will be carabid beetles, syrphids and parasitoids. A special attention will be paid to the connections between trophic web inside cultivated fields and floral stripes.

Sub task 3-3: Influence of vegetation on biodiversity, trophic foodweb structure and pest control.
Community composition and species abundance will be correlated to global characteristics of surrounding landscape and to more local floral diversity. A trait analysis will be carried out both on natural enemies and on plants. Using a correlative approach, we will test which plant species are related to low/high predator/parasitoid activity and to low/high crop herbivory. We will further try to identify plant functional traits and groups that are negatively correlated with these parameters in order to obtain more general results on plant traits that favour regulation. Symmetrically, we will assess whether these parameters are also correlated to natural enemy functional traits and explore the relationship between plant/arthropods traits. Results of the 3rd task will be combined to draw a comprehensive diagram of joint trophic network functioning of cultivated field and floral strip in interaction with landscape properties and agricultural practices. This work will allow identifying the most influential factors and species that should be entered in models developed in tasks 4 and 5.

Risks and solutions
The combination of approaches limits the risk to the task. Should the wide spectrum molecular approach prove to produce results too complex to be efficiently analyzed a more focused approach will be developed using tools targeting specific organisms (especially the pests and weeds).

Deliverables
- ✓ Toolbox for the analysis of foodwebs in agricultural landscapes (D3-1).
- ✓ Description of the actual food ranges and their variation for several arthropods considered to provide important pest control services (D3-2).
- ✓ Description of the foodweb structure based on pests and weeds, the factors influencing it and its influence on pest control service (D3-3).
- ✓ Scientific papers on ecological engineering effects on weed predation, crop pest insects, their natural enemies and crop damage with task 2 (D3-4).

3.3.3 TASK 4: ASSESSMENT OF POPULATION DYNAMICS OF PESTS AND THEIR NATURAL ENEMIES ACCOUNTING FOR THE DISTRIBUTIONS OF SEMI-NATURAL HABITATS AND AGRONOMIC PRACTICES IN THE LANDSCAPES

Responsable: Etienne Klein (BioSP) & Pierre Franck (PSH)

Contributions: BioSP; IGEPP, AE, Agronomie, SPE

Objectives

- ✓ Developing and combining ecological and genetical tools to understand and estimate population dynamics and genetic structures;
- ✓ Estimating within field population size and inter-field dispersal for pests and natural enemies accounting for the distribution of semi-natural habitats and vegetation;
- ✓ Developing statistical methods to infer demographic and dispersal parameters based on abundance and genetic data for a few important pest and natural enemy couples.

Program and Methods

Task 4 will estimate determinants of the spatio-temporal dynamics of pest and natural enemy populations as functions of landscape structure and floristic composition in fields. It will focus on the most important pests in cereal, seed grape and apple crops as in task 1 and a few predators/parasitoids couples selected based on task 3 conclusions. It will mainly use population genetic concepts to investigate the effects of the environmental factors previously determined in tasks 1 and 2 on population dynamics. **Subtask 4.1** will analyze population genetic structure in these biological systems. **Subtask 4.2** will use mark-release-recapture experiments and additional spatio-temporal records of abundance within fields and their edges to better understand movements between crops and semi-natural habitats. **Subtask 4.3** will develop mechanistic and Bayesian approaches to estimate population dynamics (notably dispersal and population size demographic parameters) for few important species that interact in selected agronomic systems. Overall, task 4, will provide qualitative and quantitative estimates of population demography, which will be used to parameterize population dynamic models in task 5.

Subtask 4.1 Developing molecular markers and analyzing population genetic structure

Molecular markers such as microsatellite loci are useful tools to understand evolutionary processes (Manel et al 2005) and infer relevant landscape variables affecting population structure and gene flow patterns (Manel et al 2003). Finer approaches to understand individual movements (Franck et al 2011) or population size (Wang 2009) also rely on molecular markers through parentage or kinship analyses (Jones & Wang 2010a) and assessment of family composition in a cohort (full-sibs, half-sib, unrelated individual). High-throughput methods for isolating markers based on coupling multiplex microsatellite enrichment and next-generation sequencing currently allow rapid and cheap development of numerous markers to achieve these analyses (Malausa et al 2011). During the first year of the project we will develop libraries in species for which such molecular resources are not currently available (eg *Meligethes aeneus*) and we will select the markers most pertinent for population genetic and kinship analyses among those available in moths (eg Franck et al 2005, 2007, 2011), aphids (eg. Guillemaud et al 2011) and their hymenoptera parasitoids (eg Hufbauer et al 2004). For other potential predators we will in collaborate with *Landscaphid* partners who already developed markers in several hoverfly (UMR Dynafor, Toulouse) and carabus (CEBC, CNRS Chizé) species. In years 2 and 3, samples collected in tasks 1 and 2 will be genotyped and we will analyse genetic structure within and among landscape sites and/or isolation-by-distance patterns. We will identify environmental factors linked with these structures (McRae 2007; Balkenhol et al 2009) for each species selected in task 1. In a second step we will analyse kinship structure in populations sampled in task 2 to estimate temporal variation of population size and compare within and among field population fitness using classical software (Jones & Wang 2010b).

Subtask 4.2 Mark-Release-Recapture experiments and assessing insect movement

The introduction of semi-natural vegetation in crop margin (task 2) may enhance pest biocontrol by attracting beneficial species from the surrounding landscape. Sub-task 4-2 will use classical tools in ecology to assess the movement of pest and beneficial species among semi-natural habitat patches, among contiguous crop fields and between both. Trapping adapted to the selected species (e.g. directional pitfall or sticky traps) will be replicated three times to coincide with the sampling in task 2 (early, intermediate and late crop development stages) in years 2 and 3. Arrays of traps will be set up to estimate the extent of movement across boundaries between the crop and semi-natural habitats and between these and the surrounding habitats. In year 3, the directional trapping study will be supplemented by the use of intrinsic-marking methods to establish the patterns of movement of selected species between semi-natural habitats and crops using immunological techniques (Jones et al 2011, Basoalto et al 2011). Furthermore, the individuals collected will be grouped by cohort and genotyped for sibship inference. We will deduce the progeny size distribution and population sizes at the field level as in sub-task 4-1. We will compare temporal samples within each studied field and among fields accounting for the presence of semi-natural habitats and floristic management.

Subtask 4.3 Statistical modelling to estimate demography of pests and natural enemy populations in heterogeneous landscapes

For species where (i) genetic differentiation is too low among populations or (ii) fine demographic observations are available, we will extend the work conducted in task 4.1 by further statistical analyses that infer demographic and dispersal parameters from mechanistic models. Although parameters in mechanistic models were classically obtained from expert knowledge or literature surveys (Vinatier et al 2012), recent computational methods in statistics such as MCMC or ABC enable to estimate them directly from *in situ* observations (Clark et al 2006, Vinatier et al 2011). In particular, Bayesian hierarchical approaches are flexible enough to combine several types of observations (e.g. abundances, genotypes and land-uses), several levels of mechanistic models and *a priori* information on the parameters (Clark et al 2006). Adoption of such methods in spatio-temporal population dynamics is recent and very promising for inference of ecological process, demographic and dispersal parameters (Soubeyrand et al 2009; Fabre et al 2010; Lindgren et al 2011; Roques et al 2012, Klein et al 2008). Monte-Carlo Markov Chains (MCMC) are particularly adapted to such hierarchical models (Beaumont et al 2004) but Approximate Bayesian Computation can also be used for more complex mechanistic models (Bertorelle et al 2011, Project ANR EMILE). Sub-task 4-3 will apply these statistical methods in order to estimate important demographic and dispersal parameters (long-distance dispersal, population growth, Allee effects, and potentially their variations linked with landscape features) for a small set of selected species couples. We will select systems with (i) contrasted biological characteristics (levels of gene flow, population densities, reproduction rates and sensitivities to landscape features) and (ii) important amounts of observed data in different landscapes. Two classes of mechanistic models will be used to represent the studied systems. First spatially explicit metapopulations (eg codling moth model) suit well to populations in different fields connected through migration rates that depend on distance, field and population sizes and landscape features. Second, reaction-diffusion and integro-difference models (eg aphids and carabids) represent well populations spread at different densities over a continuous and heterogeneous space. The evolution through time and space of the local density of individuals is governed by a local reproduction rate (reaction) and the displacement of individuals (diffusion rate). In both types of model, additionally to densities, the spatio-temporal evolution of genetic diversity also depends on the demographic and dispersal parameters (Gaggiotti et al 2002, Garnier et al 2012). Accounting for genotypic information should thus improve inferences. We will model jointly demographic and genetic dynamics when such information is available.

Risks and solutions

We intend to plug the mechanistic parameters estimated in task 4.3 into the mechanistic or individual-based models of task 5. Because models from tasks 4.3 and 5 might differ in their degree of realism and scale of interest we will investigate how the principal modelling objects can be transferred from one type of model to another. Analytical investigations and numerical simulations in simplified landscapes will be used to check the consistencies between the results from both types of models before applications in task 5.

Deliverables

- ✓ Molecular resources and associated publications to analyze population genetic structure of several important pests and natural enemies in agricultural landscapes (D4-1);
- ✓ Communication on the identification of habitats in the agricultural mosaic that affect dynamic and genetic structure in several pest and natural enemy populations with task 1 (D4-2);
- ✓ Identification of agronomic practices and vegetation that affect pest and natural enemy population dynamics with task 2 (D4.3).
- ✓ Estimation of demographic parameters and landscape features affecting population dynamic in one couple of pest and natural enemy in both cropping system (D4.4).

3.3.4 TASK 5: CONTROLLING INSECT AND WEED PESTS INFESTATION BY LANDSCAPE SUPPRESSIVENESS

Responsables: Nicolas Parisey (IGEPP) & Benoît Ricci (AgroEcologie)
Contributions: AE, IGEPP, PSH, Agronomie, EP
Objectives

- ✓ Developing a multi-scale toolkit of spatially explicit population dynamic models for both pests and their natural enemies.
- ✓ Simulation of realistic and semi-realistic landscapes
- ✓ Designing landscapes patterns for weed and insect pests control

Program and Methods

This task will use simulations of pest population dynamics on virtual landscapes, coupled with optimization algorithms, to design spatio-temporal patterns for pest control.

Subtask 5.1 Developing a multi-scale toolkit of population dynamic models

We intend to adapt and develop population dynamics models capable of reproducing how the landscape composition and its structure influence the population dynamics of some specific pests and of their natural enemies, and their inter-trophic level interactions. The modeled ecological processes will depend on knowledge about ecological requirements and behaviors of the considered species and will benefit from results of Task 1, 2 and 4. The models will include, for example, niche saturation, dispersal barriers or spatial habitat dilution in order to represent the effects of the spatial configuration of crops and agronomical practices within the landscape. In order to understand these ecological processes, which are naturally hierarchical (Kent et al, 2011), we need a set of multi-scale analysis tools, i.e. a multi-scale toolkit of models. Most of the models available through the participants of this project can fit in two categories: parsimonious population models (usually reaction-diffusion model, RDM) or highly mechanistic individual based models (IBM). Each of these types of models offers particular advantages. In the first hand, RDM provide mathematical analysis of temporal dynamics (Gaucel et al 2007, Ciss et al submitted). In the other hand, stochastic or deterministic IBM (Vinatier et al 2012) incorporate high level behavioral and/or ecological details on the pests life cycles, but does not allow for mathematical analysis and require intensive simulation exploration. Hence, the combination of these models offers a fine multi-scale (from individuals to populations) tool for population dynamic analysis. Already available models in this subtask concern (i) aphids (*Sitobion avenae*, *Rhopalosiphum padi*) and their natural enemies (Syrph, Hymenopetra parasitoids) and (ii) Meligethes (*Meligethes aeneus*) and its parasitoid (*Tersilochus heterocerus*). These models will be improved or adapted according to the results of Task 1, 2 and 4. We will complete this multi-scale toolkit by adding reaction-diffusion models for the population dynamics of weeds (*Viola arvensis*) associated to a generalist predator carabid (*Poecilus cupreus*) and the population dynamics of aphids and their natural enemies (*Aphidius ervi*, *A. matricariae*, *Episyrphus balteatus*). We will first focus on reaction-diffusion systems because these parsimonious population models enable a straightforward link with work developed in Task 4 and models used for the eco-efficiency assessment of Task 6. Later on during the project, we will introduce more ecological and behavioral complexity in our toolkit by taking into account spatially explicit metapopulation models (codling moth model, see Task 4) and available IBM models.

Subtask 5.2: Simulation of realistic and semi-realistic landscape

In order to assess landscape properties that could mitigate the impacts of pests and weeds on crop production, we need to generate realistic landscapes to be used as input data in our models. This landscape generation step will be based on available geomatic and agronomical data collected from Task 1/ Task 2 and already available in historical datasets of the same experimental sites. As we want to investigate new integrated pest management (IPM) solutions derived from landscape features, these generated landscapes need to be realistic but also to explore spatial organizations that differ from real existing landscapes. We propose to adapt available landscape simulation frameworks to our needs notably (i) Genexp-Landsites (LeBer et al 2009) that creates landscape controlling for crop plots density and shapes; and (ii) LANDSFacts (Macaulay Institute, Castellazzi et al, 2010) that allow to spatially distribute agronomical practices according to user-defined rules.

Subtask 5.3: Designing landscapes patterns for pest control

In a first step of this subtask, we will consider the case of 'static' landscape suppressiveness where landscape attributes (e.g. spatial distribution of crops, agronomical practices, pest resistance, etc.) are considered constant in time. We plan to assess whether landscape heterogeneity, in itself, can dampen epidemic spread or, at least, involve a privileged direction for the epidemic wave. Hopefully, this would enable us to identify spatial patterns that could help in designing suppressive landscape. The different teams involved in this project are quite familiar with such approaches. The project gives the opportunity to explore the dynamics of several sets of pests and their natural enemies, and their interactions, within the landscape. In a second step, we will consider 'dynamic' landscapes, i.e. a spatially heterogeneous entity that varies over time (Baudry & Burel 2003). The system formed by the population dynamics of pests and their natural enemies, on one hand, and the landscape dynamic, on the other hand, is complex. Indeed, this system is (i) nonlinear (both in time and space) (ii) susceptible to initial conditions and (iii) showing many feedback loops. While more complex to assess, the spatio-temporal patterns that could be extracted from such study would be invaluable in the context of IPM. These patterns could explore the importance of crop rotation; pesticides use reduction, and many other time-dependent, spatially heterogeneous agronomical practices. Both 'static' and 'dynamic' landscape suppressiveness will be explored using models from subtask 5.1 coupled with multi-objective optimization algorithms e.g. evolutionary algorithm and particle swarm (Coello et al 2007). Such algorithms aim at minimizing or maximizing simultaneously several criteria (for example minimizing the amount of pest damage on crops) with respect to a set of constraints on the decision variables (for example by respecting realistic landscape with a given utilized agricultural area). Those algorithms are known to be suitable to a wide range of model types as long as they can provide numerical output, which is the case of all our models.

<u>Risks and solutions</u>

Exploration of IBM by optimization algorithms may induce high computational cost. This could be partially solved by algorithmic adaptation to parallel calculus.

<u>Deliverables</u>

- ✓ 2-3 new models and existing models adapted to the goals of task 6 (D5-1).
- ✓ Extraction of dynamic landscape pattern for controlling pest mediated plant epidemics (D5-2).
- ✓ Scientific publications in peer-reviewed international journals about population dynamic models in link with tasks 4 and 6 (D5-3).

3.3.5 TASK 6 ECONOMIC AND AGRO-ECOLOGICAL PERFORMANCES OF LAND-USE PATTERNS AT A LANDSCAPE LEVEL, AND IDENTIFICATION OF VIABLE MANAGEMENT STRATEGIES TO CONTROL INSECT AND WEED PESTS

Responsible: Vincent Martinet (EP) & Mohamed Ould Sidi (PSH**)**
Contribution: EP, PSH & IGEPP
Objectives:
This task aims at assessing the economic and agro-ecologic performance of land use pattern scenarios. Three main issues will be addressed:

- ✓ Build the eco-efficiency production frontier of the landscape, using the optimization and simulation approaches of Task 5, completed with economic analysis of the related production systems.
- ✓ Develop tools to measure the distance to the eco-efficiency frontier of given land use patterns, in particular, patterns driven by territorialized agri-environmental schemes.
- ✓ Assess the economic acceptability of alternative agricultural practices, and cost-benefit analysis of given policies to control insect and weed pests.

Detailed research program:
The objective of task 6 is to provide a socio-economic analysis of the management strategies proposed to control insect and weed pests. On the one hand, this task will describe the trade-offs between the various dimensions of agricultural production at the landscape scale. On the other hand, this task will develop analytical tools to evaluate the social interest of implementing given management strategies. In this task, the focus of the analysis will be reduced to four important dimensions of the performance of the agro-ecosystems at the landscape level: the produced quantity, the gross margin, an environmental index (e.g., the IFT) and an ecological index (e.g., the expected abundance of pests).
Task 6 will be divided into three interconnected sub-tasks.
Sub-task 6.1 will use the simulation results of task 5 to build the eco-efficiency production possibility frontier. This frontier is a representation of the necessary trade-offs between the considered criteria listed above. The agro-ecological data generated by the models of task 5 will be completed with economic data to provide multidimensional outcomes for each landscape scenario. The economic data will be collected from various sources: available agro-economic data for related agricultural practices, surveys of the farmers involved in the various field experiments, and experimental economics. A specific valuation method, based on choice experiment to reveal the willingness to accept of farmers faced with alternative practices to regulate pest risks and mitigate associated costs, will be developed for that purpose.
Pareto efficient points (points on the eco-efficiency frontier) may correspond to land-use patterns that are not easily achievable. Realistic land-use patterns would lie strictly within the set of feasible outcomes. Therefore, **sub-task 6.2** will define instruments to measure the distance of a given land use pattern to the frontier, and assess the performance of the associated scenario. Different measurement tools will be examined. This analysis will reveal how far from the Pareto frontier is the current (business-as-usual) agricultural land-use, and what could be the gains of improving eco-efficiency.

Sub-task 6.3 will define incentive instruments to reach land-use patterns that are more eco-efficient. This requires assessing the cost of adoption of some innovative agro-ecologic practices, and the interactions of private agents over the landscape. Cost-Benefit analysis will be used to assess the social interest of these public policies. This Cost-benefit analysis will take into account the heterogeneity of farmers' profits/preferences regarding the program. As the temporal stability of landscapes, or the maintenance of particular dynamic land use practices, may be important to achieve targeted ecological goals, we shall examine the intertemporal aspects of management practices. In particular, we will study the viability of the proposed practices and associated policies in a context of uncertain agricultural prices.

Methods, technical choices and solutions:
To construct the production possibility frontier (sub-task 6.1) we shall model the agro-ecological and economic outcome of landscape from the models developed in task 5. Economic and agro-ecological models will be integrated with scientific software and ad hoc calibration with data from other tasks. The estimation of the implementation cost of the studied scenarios will be partly based on experimental economics approaches. Participating farmers will choose between different options regarding some agro-economic programs. These programs will describe the rotations, the reduction in pesticides/fertilizers use along with the resulting expected yield, the probabilities of bad events and an estimation of their resulting gross margin. Farmers will reply to different choices and a logit estimation will determine their preferences. These preferences will be useful for calibrating a profit function with specific preferences regarding the risk of bad crops

Deliverables:
- ✓ Parametric (Pareto) eco-efficiency frontier of the landscape agro-ecologic and economic production – Methodology and internal report to the project (D6.1)
- ✓ Metrics (measurement tools) to evaluate the distance of an outcome to the Pareto-efficiency frontier – Methodology and internal report to the project (D6.2).
- ✓ Scientific publications in peer-reviewed international economics and environmental journals in collaboration with other tasks (D6-3).

Risks and solutions
The acquisition of relevant economic data will strongly depend on the type of agro-ecological scenarios proposed by the other tasks. Our strategy is to diversify the potential sources of data, from public data and individual survey, to experimental economics data, in order to start the economic analysis from the beginning of the project (mainly the theoretical points first, and application from year 2) to avoid a concentration of the contribution of this field at the end of the project.

3.4. TASKS SCHEDULE, DELIVERABLES AND MILESTONES

The following table corresponds to task schedule along 48 months with indication about dates of each deliverable.

Month	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
T1.																
T1.1:				D 1-1												
T1.2:										D 1-2						
T1.3:												D 1-3				
T2.																
T2.1														D 2-1		
T2.2:												D 2-2				
T2.3:										D 2-3						
T3.																
T3.1:			D 3-1											D 3-3		
T3.2:											D 3-2					
T3.3:														D 3-4		
T4.																
T4.1:														D 4-1		
T4.2:														D 4-2		
T4.3:														D 4-3		
T5.																
T5.1:										D 5-1						
T5.2:										D 5-2						
T5.3:																D 5-3
T6.																
T6.1:																D 6-1
T6.2:										D 6-2						
T6.3:																D 6-3
T7.																
T7.1:																
T7.2																

4. DISSEMINATION AND EXPLOITATION OF RESULTS. INTELLECTUAL PROPERTY

The *PEERLESS* proposal is mostly based on a comparative and highly integrated approach bringing into play most of the partners. It is not on the juxtaposition of partly independent studies. Consequently, results promotion will be carried out in cooperation. This will require concentration and several time periods will be organized in task 7 to promote it.

Scientific communication. The partners implied in the *PEERLESS* proposal have an important experience of publications in high-ranked scientific journals. The scientific issues in *PEERLESS* will be of interests for large audience disciplinary journals (eg. *Ecology* or *Molecular Ecology)* and academic journals at interfaces between economy, ecology and agronomy (eg. *Journal of Applied Ecology*, *Ecological Economics*, *Agriculture Ecosystems & Environment*). The *PEERLESS* project will also complete the lack of integrated landscape data require to understand ecological process and contribute to review articles. Consequently, an important scientific production both in quality and quantity can be expected. The collaborative character of most of the studies should result in the production of a high proportion of joint publications between participating partners. A collective strategy of presentation of common result into international conferences (eg OILB, entomophagous conferences) will be elaborated during the annual meetings. Finally, vulgarization papers for professional and general public (eg *Phytoma, Biofutur*) will also ensure nationally the visibility of *PEERLESS* results.

Public outreach. The importance of *PEERLESS* issue in the context of the undergoing radical transformation of agriculture confers to the participating a particular duty concerning the transfer of practical results to farmers, stakeholders involved in regional and agronomic development. Reports to farmers who will be surveyed during the project, scientific animations organized in the different long-term monitoring areas (eg Pleine-Fougère, Vergers de la Basse-Vallée de la Durance) and pedagogical initiatives for students in agronomic schools (notably at agrocampus-ouest) will be coordinate to promote transfer in the studied site. Participation of *PEERLESS* teams to finalized programs, especially CASDAR and Ecophyto programs devoted to connected questions will also be very favorable to transfer results to professionals and for possible application in DEPHY farms (Démonstration Expérimentation Production de références sur les systèmes économes en pHYtosanitaires). Furthermore, we will invite representatives of technical institutes, CETIOM, and GRAB, as external advisors to annual *PEERLESS* meeting. Altogether, this will insure a large dissemination of *PEERLESS* results in the agricultural sphere.

Practical issues. Altogether, the scientific communication planning should establish the *PEERLESS* network as a leader group in the field of ecological engineering for pest management both at national and international scale. *PEERLESS* is clearly in accordance with the scientific strategy of INRA and will contribute to the aim of optimizing the use of ecological processes in agricultural production advocated during the 'Grenelle de l'Environnement'. Practically, it will provide a rigorous assessment of landscape value for the improvement of natural pest control. The findings of *PEERLESS* will be precious for professionals aiming at reducing pest pressure on crops through suppressive landscape.

Multicriterium evaluation of current and alternative crop practices and the design of viable landscape for farmers will also helpful to define public policies. Considering the importance of the crop studied (wheat, seed rape, and apple) in term of national plantation area and/or pesticide consummation, the *PEERLESS* proposal may importantly contribute to the achievement of the ECOPHYTO 2018 action plan.
An important by-product of *PEERLESS* will be the production or the enlargement of important reference databases for *i*) the molecular identification of beneficial groups of high agricultural importance (syrphids, hymenoptera parasitoids, carabids), *ii*) establishment of their trophic link with agricultural pests and *iii*) the crossing of agronomic practices with their ecological impacts.
Finally, *PEERLESS* will importantly contribute to the structuring of a French scientific network in the field of agroecology.

5. CONSORTIUM DESCRIPTION

5.1. PARTNERS DESCRIPTION & RELEVANCE, COMPLEMENTARITY

The PEELESS consortium will group together six different INRA partners:
Partner #1 Plantes et Systèmes de culture Horticoles (PSH), UR1115, Avignon is mainly involved in agroecology in Horticultural Plants and cropping Systems. PSH will coordinate the *PEERLESS* project, will co-coordinate tasks 1, 4 and 6 and will be involved in all the tasks.
Partner #2 Agronomie, UMR211, Grignon is devoted to the design and assessment of innovative and sustainable cropping systems taking into account several crops and diverse biotic and abiotic factors. The two main research activities are (1) design and assessment of cropping system at field scale and at landscape scale, (2) the analysis of crop-pests interaction at field level. The unit develops/uses a diversity of models (eg model named Sippom and Mosaic Pest), statistical methods and expert knowledge on various crops and also at the scale of the cropping system and landscape level. Agronomy will be involved in tasks 2 to 5.
Partner #3 Institut de Génétique Environnement et Protection des Plantes (IGEPP), UMR1349, Rennes & Angers have skills in vegetation and plant sciences, plant proctection and ecology. IGEPP has the ambition to understand the evolution of plant-phyphagous interaction and their adaptation to the agro-ecosystem in order to propose sustainable crop productive systems. IGEPP will be involved in all the tasks and will co-coordinate tasks 2, 3 and 5.
Partner #4 AgroEcologie (AE), UMR1347, Dijon, involved in issues associated with the conception and the evaluation of agricultural systems that satisfy both food production and environmental criteria. AE participants to *PEERLESS* belong to "Community ecology and sustainability of agricultural systems" team, which studies links between agricultural systems, functioning of communities and the agroecological services provided by these communities. AE mainly observe, model the impact of agricultural practices on the weed

flora and their natural enemies. AR will be involved both at the local and the landscape scale, and the development of models in task 1 to 5 and co-coordinate task 1, 3 and 5.

Partner #5 Biostatistique & Processus Spatiaux (BioSP), UR 546, Avignon develops therotical and applied research in statistics, spatial and spatio-temporal modeling. BioSP have a particular interest on applied questions about environment, ecology, epidemiology and population biology. BioSP will co-coordinate task 4.

Partner #6 Economie Public (EP), UMR INRA-AgroParisTech, Grignon, develop research and teaching in applied economics in the fields of agriculture and the environment. Research focuses on environmental and public policy concerns in the agricultural and agribusiness sectors. EP develop methods, simulation models, and tools that can be used by economic policy makers and, more broadly, by all social actors. EP will provide its expertise on environmental and agricultural economics and policies to *PEERLESS*. EP will be involved in tasks 1 (collect economic data), 5 (economic aspects of the studied agro-ecological models) and 6, and will co-coordinate task 6.

Complementarily among partners:

	PSH	Agronomie	IGEPP	AE	BioSP	EP
Crop experiences	Perennial	Annual	Annual	Annual		
Botany			X	X		
Entomology	X	X	X	X		
Agronomy	X	X	X			
Community Ecology	X		X	X		
Landscape Ecology	X	X	X	X	X	
Spatial statistics					X	
Modelling	X	X	X	X	X	X
Molecular biology	X			X		
Population dynamics	X			X	X	
Engineering sciences	X					X
Landscape design						X
Economics						X

The *PEERLESS* partnership has been designed to tackle the challenge posed by the necessity **to gather all required competences to achieve the objectives of the project** and at the same time not to scatter resources by **including too many teams.** *PEERLESS* gathers partners who are experts in the domains they are involved in the project (agronomy, landscape and community ecology, spatial statistic, crop sciences, engineering sciences and economy) and also have recognised expertise on farming systems comprising apple orchards or W/OSR crop rotations). All partners have some expertise in modelling. They have been previously involved in national ECOGER, ADD (Gedupic), 'blanc' (EMILE) and thematic ANR programs (DynRurABio, BiodivAgriM) and their management (Landscaphid, Advherb, 'Eco des vergers'). **All partners have multidisciplinary interest** and some (AE, IGEPP,PSH) correspond to multidisplinary units. IGEPP, AE, Agronomy and PSH partners have been carrying field work in commercial fields with technical advisors or extension services formerly. PSH and AE are involved in projects that evaluate pesticide use reduction in experimental and DEPHY farm networks (EXPE-Ecophyto, CASDAR 'Vergers bas-intrants', Alt'carpo) and Integrated Crop Protection Network ("Réseau PIC"). Furthermore, IGEPP, AE, and PSH are members of the collaborative SEBIOPAG network (https://www.rennes.inra.fr/sad/media/documents_lies/projet_soere_sebiopag_2011) involved in long-term analyses of ecosystem services provided by the biodiversity in agricultural landscapes. IGEPP, BioSP and PSH are also involved the "Payote" network that develop models of agricultural landscape. This is particularly important in such a project that aims to bind together **knowledge and expertise from different scientific fields** to investigate the whole causal chain linking semi-natural habitat management to crop productivity *via* its impact on pest control and to ensure that proposed solutions are acceptable both by practitioners and authorities.

5.2. QUALIFICATION OF THE PROJECT COORDINATOR

The global coordination will be ensured by Pierre Franck (PSH), who is researcher at INRA since 2002. His INRA scientific project aims at analysing insect population dynamics and developing biocontrol strategies to limit pest expansion and overlaps with central objectives of the *PEERLESS* project. Pierre Franck managed two phD and seven Master students since 2004 and he advised several phD French and international students in the frame of bilateral exchanges (eg. Platon, PRAD and Fondecyt projects). Pierre Franck previously managed INRA projects including one about pest control detection based on analyses of spatio-temporal heterogeneities in biodiversity (2009-2011). He co-animated a task on insect pest dynamics in agricultural landscape (ECOGER program "Eco des vergers", 2006-2009). He currently involved in the pesticide program "Alt-carpo" from the national EEDDAT ministry (2010-2013), the European project PURE (2011-2015) and he is external advisor of the ANR systerra program "Landscaphid" (2010-2013). Several researchers involved in these programs will participate to *PEERLESS*. This strong partnership and the time Pierre Franck can investigate in the project are some guarantees for an efficient management, which will be ensured in task 7 with the help of all the task leaders.

5.3. QUALIFICATION AND CONTRIBUTION OF EACH PARTNER

The staff hired on the project can be found in part 6.

Partner	Name	First name	Position ***	Person. months**	Contribution to the project 4 lignes max
PSH/ Coord.	FRANCK	Pierre	CR	20	Task 4, *PEERLESS* coordinator. Landscape genetics and food web structures.
PSH	Lavigne	Claire	DR	12	Co-coord. task 1. Landscape ecology, statistics (T1, 4).
	Capowiez	Yvan	CR	5	Pest -predators interactions (T 2 , 3).
	Ould Sidi	Mohamed	CR	12	Co-coord. Task 6. Parameter estimation, optimization (T 5, 6)
	Toubon	Jean-	AI	12	Farmers surveys, field work

		Francois			
	Thomas	Cécile	TR	12	Arthropod identification
	Mascle	Odile	TR	5	
	Olivares	Jérôme	TR	24	Molecular biology (T 3 , 4)
	Lescourret	Francoise	DR	0.2	Overall scientific expertise (T7), link to the EU FP7 PURE project.
	Maugin	Sandrine	TR	3	Maintenance and rearing of arthropods
Agronomie	Valantin-Morison	Muriel	CR	12	Co-coord. task 2 ; agricultural practices (T2,3). Population dynamics (T4). Models (T5)
	Gosme	Marie	CR	12	Agricultural paractices (T2,3). Model design and parametrisation (T5)
	Bazot	Mathieu	TR	12	Technical assistance - Field survey observations in annual crops
	Butier	Arnaud	TR	20	
IGEPP	Bischoff	Armin	MC	20	Co-coord. (task 2) analysis of vegetation effects on plant-insect interaction (T1,3)
	Jaloux	Bruno	MC	12	Plant-insect interaction, food-webs (T1-3)
	Lecorff	Josiane	Pr	9	Multitrophic interactions (T 2,3)
	Tricault	Yann	MC	14	Landscape, cropping and vegetation effects (T1,2,3)
	Braud	Ferréol	TR	4	Technical support (T1,2,3)
	Plantegenest	Manuel	MC	18	Co-coord task 3. Landscape ecology, trophic networks (T1,2,3)
	Parisey	Nicolas	IR	20	Co-coord. task 5. Analysis of community dynamics. Modeling (T 3, 4 ,5)
	Poggi	Sylvain	CR	12	Modeling (T 4, 5)
	Le Ralec	Anne	MC	8	Aphids/parasitoids networks (T 1, 2, 3)
	Outreman	Yannick	MC	8	Aphids/parasitoids networks. Population genetics of parasitoids (T2, 3, 4)
	Chaubet	Bernard	AT	3	Parasitoids, syrphids, carabids and aphids identifications (T1,3)
	Querrien	Marie-Thérèse	TR	6	
	Turpeau	Evelyne	TR	1.5	
	Krespi	Liliane	MC	4	Ecology of parasitoids (T4,5)
	Simon	Jean-Christophe	DR	4	Environmental and pop. genetics (T4,5)
	Mieuzet	Lucie	AI	4.5	Molecular analyses (T4)
	Stoeckel	Solenn	CR	4	Population genetics and modeling (T4)
	Raymond	Lucie	PhD	2	Population genetics of syrphids (T4)
	Polin	Sarah	PhD	4	Aphid natural enemies (T3)
	Kamenova	Stefaniya	PhD	2	Molecular analyses of trophic networks (T3)
	Andrade	Thiago	PhD	2	Aphids parasitoids community (T3)
AE	Petit	Sandrine	DR	12	Co-cord. task 1 ; landscape ecology, Weed seed predation (T1, 2,3,4)
	ChauvelL	Bruno	CR	10	Agricultural practices, weed flora (T 1,2)
	Ricci	Benoit	CR	12	Co-coord. task 5. Spatial population modeling

					(T4,5)
	Gaba	Sabrina	CR	8	Models trophic interactions, statistics (T4,5)
	Bohan	David	Post-doc	9	Co-cord. task 3. Food webs, statistics (T1,3)
	Biju-Duval	Luc	AI	8	GIS (T 1)
	Auguste	Cyrille	TR	18	Task 1, 2, 4 Field survey (T 1,2,4)
	Ducourtieux	Chantal	TR	18	Task 1, 3, 4 Fied survey (T1,3,4)
	CADET	Emilie	AT	10	Weed surveys (T 1, 2)
BioSP	Bonnefon	Olivier	IR	8	Simulation of spatio-temporal dynamics, parameter estimation (T 4.3)
	Klein	Etienne	DR	5	Co-coord task 4.Spatial statistics coupling demographic and genetic observations
	Roques	Lionel	CR	5	Mathematical models of spatio-temporal dynamics (T4).
	Soubeyrand	Samuel	CR	5	Spatial epidemiology and statistics on demographic and genetic observations (T4)

					Field of research*	Contribution to the project
Economie Publique	Martinet	Vincent	CR	8	Environmental and Ecological economics	Co. coord. task 6. Economic and agro-ecologic performances of production systems
	Bureau	Jean-Christophe	Pr	4	Agricultural economics	Construction of production possibility frontiers, and measures of efficiency.
	Marette	Stephan	DR	6	Agricultural and Experimental Economics	Farmer adoption of alternative production. Benefit-Cost analysis of public policies.
	Desbois	Dominique	IE	6	Micro-economics of agricultural production	Economic data analysis. production possibility frontiers.
	Lusk	Jayson	Pr	1	Experimental economics	External collaborator. Economics experiments (Oklahoma State Univ.)

* to inform only for social sciences
** over the total project duration
*** Pr : Professor, Dr : senior scientist, CR : junior scientist, MC : assistant professor, IE : engineer, AI,TR,AT: three categories of technicians

6. SCIENTIFIC JUSTIFICATION OF REQUESTED RESSOURCES

6.1. PARTNER 1 : PSH (AVIGNON)

Equipment

An additional thermocycler will be necessary to perform the PCR programmed in this project at the molecular platform in Avignon **(9.5k€)**.

Staff

Posdoctoral fellow (15 months): The post-doctoral fellow will work on optimization of land-use patterns for the control of pests and weeds by naturally occurring pest-enemies (tasks 5 and 6). The recruited person should have a PhD in applied mathematics and skills in modeling and/or non linear multi-objective optimization. He will be supervised by Mohamed-Mahmoud Ould-Sidi (optimization, PSH) and Nicolas Parisey (modeling, IGEPP) **(60 k€).**

Training course: 3 training courses of 6 months from year 1 to 3. The students will participate to answer scientific questions in tasks 1, 2 and 3. **(7.7 k€)**

Technical help for field work (6 months 1st year and 5 the 2nd year). The recruited persons will help with field samplings and characterization of local and far landscape (**25.4 k€**).

Travel

Task1 (4 k€)	Landscape characterisation and farmer survey: (15€ per day per person, 30 person.days per year): 2*30*15~ 1k€ Seasonal field work (60 person.days, 2 years): 60*15*2 =1.5k€ Meetings between field sites with orchards (to Pleine-Fougères) 3*500€= 1.5k€
Task 2 (1.5k€)	Field trips to the experimental site of Gotheron (130 km*0.37€= + 15€)* 10 * x 2 years = 1.3k€ . The other site is close to the PSH lab.
Task 3 (4k€)	Field trips for specific collection of individuals for gut content analyses and parasitism. Trips have to be short for a good conservation of samples. Seasonal field work (60 person.days, 2 years): 60*15*2 =1.8k€ Trips to other sites to group samples for molecular biology =2.2k€
Task 4 (1.5k€)	Travels to fields specific for population genetic and dynamics analyses (50 person.days, 2 years): 50*2*15=1.5k€
Task 5 and 6 (6 k€)	Travel for post-doc and supervisor between Rennes, Avignon and Grignon every 3 months to ensure work coherence: 5x1000=5k€ Travel between sites before and after post-doc: 500 x 2=1k€
Task 7 (13.5k€)	This travel money is meant for intermediate meetings between task coordinators and for annual meetings of the project for members of the PSH unit and for invitation of all external members with which the project has links (technical advisers from GRAB, CTIFL and CETIOM). Travels to annual meetings 250€ per travel/stay, 4 persons x 4 meetings: 4k€ Invitations to annual meetings 250€ per travel/stay, 3 persons x 4 meetings: 3k€ Intermediate meetings for coordination 250€ per travel/stay, 2 persons x 4 meetings: 2k€

Travel to scientific meetings for all project participants (e.g. IOBC, ICE)= **4.5k€**

Costs justified by internal procedures of invoicing

Fees to the experimental unit (INRA, Domaine Saint-Paul, Avignon) for orchard management for task 2 : **3k€**

Other expenses

Major expenses :

Task 2	Seeds for flower strips and field material: **1k€**
Task 4	Genotyping *A.quadridentata* 20 sites x 40 individuals x 4 dates (extraction 2€ + 2 PCR 2€) = **12.8k€**
Task 3	Routine identification of larvae parasitoids 20 sites x 40 Cp individuals x 4 dates = **3.2k€** Molecular identification of preys in predator guts Sequencing **10k€**
Task 5	Computer and small material for the post-doc student : **1k€**
Tasks 1-4	Field expenses (collecting vials, cardboard and pitfall traps)= **5k** €

Management fees by INRA (4%) **7.4k** €

6.2. PARTNER 2 : AGRONOMIE (GRIGNON)

Staff

PhD student 18 months (50%): task 4 ; year 1-3; :This person will set-up and use microsatellite markers on pollen beetle in order to qualify the genetic structure of populations and to progress in the knowledge of the effect of landscape patterns on their population dynamics. This Student will be supervised by UMR Agronomy and PSH: **(44.6 €)**

Training course: 5 training courses of 6 months from year 1 to 3. The students will participate to answer scientific questions in tasks 2, 3 and 4. **(12.4 k€)**

Travel

Trap pests, natural ennemies and plants measurements ; Travel expenses to the fields or to the meeting of the project; 3 International congress for 2 persons **(20k€)**

Costs justified by internal procedures of invoicing

Implementation of specific trials for cropping systems effect with or without field margins in Versailles and Grignon during 4 years **(6.4k€)**

Other expenses

Development of specific molecular tools; Computer **(36 k€)**

6.3. PARTNER 3 : IGEPP (RENNES, ANGERS)

Personnel / Staff

Posdoctoral fellow 12 months: Food web analyses base on gut contents analyses and next generation sequencing**. (40k€)**
PhD grant 18 months (50%): : The influence of field margins vegetation on pest insects and their predators – optimisation of the wildflower strip approach

Co-funding of the thesis will be requested in 2013 (Region Pays de la Loire). Objective 1 is closely related to task 1, objective 2 to task 3 and objective 3 to task 2. The thesis will be co-supervised by the coordinators of task 2 and 3. (**45.8k€)**
Training courses*:* Several stays will be proposed every year to master students to analyze the effects of ecological processes on the abundances of pests and pest enemies or to develop modeling and parameters estimations from field data **(66 months = 28k€)**

Prestation de service externe / Subcontracting

The establishment of sown wild flower strip needs a collaboration with seed suppliers who (i) can provide regional wildflower seed of desired species or (ii) if not available, can multiply seed of our own collections. The seed company Novaflore specialised in wildflower seed production will be involved as a subcontractor (**2k€**)
We also need help of the farmers to prepare field or field margins for sowing of wildflower strips. Subcontracts will include compensation for yield loss and/or field preparation **(1k€)**

Missions / Travel

Task1 ***(10.2 k€)***	Landscape characterisation and farmer survey: (15€ per day per person, 30 person.days per year): 60*15*2~ 1.8 k€ Seasonal field work (60 person.days, 2 years): 120*15*2 =3k€ Vegetation survey at all sites: 80 * 15 * 2 years: 2.4k€ Meetings between field sites 6*500€= 3k€
Task 2 ***(7.5 k)€***	Field site selection and sowing wildflower strips at Angers: 80*15 = 1.2k€ Assistance at other test sites: 120*15=1.8k€ Seasonal field work: 120*15*2=3k€ Meetings between field sites: 3*500€=1.5k€
Task 3 ***(4 k€)***	Field trips for specific collection of individuals for gut content analyses and parasitism. Trips have to be short for a good conservation of samples. Seasonal field work (60 person.days, 2 years): 60*15*2 =1.8k€ Trips to other sites to group samples for molecular biology =2.2k€
Task 4 ***(1.5k€)***	Travels to fields specific for population genetic and dynamics analyses (50 person.days, 2 years): 50*2*15=1.5k€
Task 5, 6 ***(3 k€)***	Travel for meetings to ensure work coherence: 6x500=3k€
Task 7 ***(6k€)***	Travels to annual meetings 250€ per travel/stay, 4 persons x 4 meetings: 4k€ Intermediate meetings for coordination 250€ per travel/stay, 2 persons x 4 meetings: 2k€
Dissemination ***(6k€)***	Presentation of the project and results at national and international conferences: 3 persons * 2 conferences

Autres dépenses de fonctionnement / Other expenses

Major expenses :

Task 1+2	Various expenditures for field collection and survey : **15k€**

	GIS licence/statistics software: **3k€**
Task 2-3	Analysis of stable isotopes 10 sites x 50 individuals: **5k€** Molecular identification of preys and pollens in predator guts Sequencing **16k€**
Task 4	Microsatellites for *A. matricariae*: **5k€** Genotyping *A.ervi* and *A. matricariae* 20 sites x 60 individuals x 4 dates= **10 k€**
Task 1-5	Computer for post-docs, PhD and master students (4): **6k€**

INRA management fees (4%) **5k €**

6.4. PARTNER 4 : AGROECOLOGIE (DIJON)

Équipement / Equipment

2 sets of GPS Trimble and associated exploitation systems: **8 K€**

Personnel / Staff

CDD IR2 (12 months): the appointed candidate will lead the development of the database developed within task 1 and liaise with task 5 and task 6 for data dissemination. The first milestone is the design of a common *PEERLESS* database with the objective of collating the landscape, agronomic, biological and socio-economic data acquired by the different partners in previous projects. He/she will then analyse the database in order to identify data gaps in terms of the range of landscape and agronomic situations covered; this analysis will feed into sub-task 1.2 (data acquisition)
CDD TR (2 * 4 months): the appointed candidate will collect biological data in sub-task 1.2. He/she will bring missing expertise on insect pests not studied within the UMR, i.e. pollen beetles, aphids for collection in the Côte d'Or region.

Missions / Travel

- Travel expenses for biological, agronomic and socio-economic data acquistion in task 1,2 and 4 ; collection of carabids for gut content analyses (task 3) : **10 K€**
- Travel expenses for *PEERLESS* annual meetings, *ad hoc* workshops and attendance to conferences: **10 K€**

Other expenses

- Laptops for field work, PC for modelling & database management, GIS licences: **10 K€**
- Material for field work in taks 1, 2, 3, 4 (Pitfall traps and roofs, weed seeds, material for storing insects, expenses for sending biological material to other partners): **15 K€**
- Physico-chemical analyses of soil (in relation to weed flora) : **10 K€**
- English editing for scientific publications: **5 K€**
- Small furnitures: **6 K€**

6.5. PARTNER 5 : BIOSP (AVIGNON)

Staff

Posdoctoral fellow 12 months in biostatistic and ecology to development and test spatial statistical methods. Application to codling moth datasets **(40k€)**

Travel

Travel between Avignon and Rennes for cooperative researches and project coordination (tasks 4 and 7); international congress (**8k€**)

Other expenses

Computers including server for calculation on clusters and laptops **(7k€)**

6.6. PARTNER 6: ECONOMIE PUBLIQUE (GRIGNON)

Travel

An annual basis of **5 k€** is considered for travel costs. This amount corresponds to field experiments (economic data collection in task 1) the first year, along with project management meetings. The dissemination of results in seminars and conferences implies additional travel costs from year 2 on. Year 3 also benefits from additional travel costs due to need of long visits for the links between tasks 5 and 6 (total **10k€**). Part of the travel cost will be used for international collaborations (either inviting some international specialists for a couple of weeks, or visiting them in order to develop scientific publications from the already obtained results).

Other expenses

The budget of other expenses is scheduled on an annual basis of **5 k€**, shared between interns and small equipment. Additional budget on years 2 (total 8k€), 3 (total 14k€) and 4 (total 8k€) are required for economic field experiments (experimental economics. Task 6.1 and 6.3).

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8. Appendices

Note importante : les annexes au document scientifique doivent être déposées sur le système de soumission sous forme de documents séparés.

8.1. National and International Projects Involved *PEERLESS* Partners

8.1.1 European Projects

PURE (2011-2015) : Innovative crop protection for sustainable agriculture (http://www.pure-ipm.eu) (coord. F. Lescouret)

8.1.2 National Research Projects

ECOGER ECCO des vergers (2005-2008) : Ecologie pour la Gestion des Ecosystèmes et de leurs Ressources (coord. F. Lescouret, PSH)

ADD Gédupic (2007-2009) : La protection intégrée des cultures : construire et favoriser une gestion écologique de la santé des plantes (coord. P. Ricci)

ANR Biodiversité BiodivAgriM (2008-2011) : scenarii of landscape changes on the distribution, abundance and persistence of biodiversity in agroecosystem (coord. V. Bretagnole)

ANR Systerra Advherb (2009-2012): Gestion agro-écologique de la flore adventice dans des systèmes à bas niveaux d'herbicides (coord. S. Petit, AE)

ANR Blanc EMILE (2009-2013) : Études de Méthodes Inférentielles et Logiciels pour l'Évolution (coord. JM. Cornuet)

ANR Systerra landscaphid (2010-2013) : Influence du paysage sur les pucerons ravageurs des cultures et le potentiel de contrôle biologique - Application à l'ingénierie écologique pour la gestion des ravageurs (coord. M. Platagenest, IGEPP)

ANR Systerra DynRurABio (2011-2014) : Dynamiques de développement de l'Agriculture Biologique pour une écologisation des territoires (coord. M. Tchamichan).

8.1.3 Other National Projects

CASDAR Vergers bas-intrants (2011-2012) : Arboriculture à faible niveaux d'intrants : Acquisition de références technico-économiques et environnementales dans le cadre d'un réseau de parcelles structurées en « essai système ». Coordonné par V. Mercier (UE Gotheron) et la Chambre d'agriculture PACA

EXPE-Ecophyto (2012-2016): Multicriterium evaluation of alternative orchard system (coord. S. Simon, UE Gotheron)

INTRANBA (2009-2012) : INteractions TRophiques et systèmes de culture innovants économes en intrANts: application à l'utilisation de légumineuses dans les cultures de BrassicAcées

8.2. PEST AND BENEFICIAL IN PERENIAL AND ANNUAL CROP SYSTEMS

8.2.1 PESTS AND BENEFICIALS IN APPLE ORCHARDS

Due to their multilayer structure, apple orchards could play an important role in the conservation of biodiversity if their management was more environmentally friendly (Simon et al 2010; Brown 2012). Most orchards are indeed very intensively management and non organic farmers make use of neurotoxic broad-spectrum insecticides that are detrimental for the environment (Bouvier et al 2011). Apple orchards remain one of the most intensely treated crop in France in spite of relatively low cultivated area (Butault et al 2010)

Main pests

Tortricid moths (Lepidoptera: Tortricidae) are particularly detrimental insect pests because their larvae directly feed in the fruits. As damaged fruits cannot be sold, the economic damage threshold is low and farmers have little tolerance of such pests. Consequently, insecticide treatments are frequent in regions where these pests are present. In of the Mediterranean regions, over 70% of insecticide treatments in conventional apple orchards are targeted against the codling moth, *Cydia pomonella* (Linné) (Franck et al 2005), which, as a consequence, has developed resistances to most insecticides (Reyes et al 2009). Three aphid pests are also of economic importance in European apple orchards, the rosy apple aphid, *Dysaphis plantaginea* (Passerini), the green apple aphid, *Aphis pomi* (de Geer) and the woolly apple aphid, *Eriosoma lanigerum* (Hausmann) (Marc and Canard 1997). The rosy apple aphid is the most frequent and detrimental aphid causing large yield reduction (Blommers et al 2004; Qubbaj et al 2005). The woolly apple aphid can locally be responsible for high fruit damage notably because of secondary fruit contamination by fungi. *Aphis pomi* and *E. lanigerum* complete their life-cycle on apple while *D. plantaginea* alternates between apple (primary host) and herbaceous plants (secondary hosts). Due to their exponential growth rate and their high damage risk, insecticide control is initiated at very low population level (Minarro et al 2005).

Predators of codling moth larvae and of aphid colonies.

Few generalist predators are responsible for predation of larvae in autumn among which carabids (*Pseudoophonus griseus and P. rufipes)* and Lycosidae spiders (Boreau et al 2012). Predation of aphids is primarily performed by syrphids that arrive first, followed by coccinellids and earwigs (Dib et al 2010). Predation by spiders was also observed early in spring before aphid colonies grow (Boreau et al submitted).

Parasitism of codling moths larvae and of rosy apple aphid

Diapausing larvae death through parasitism is a second other target as these larvae are the basis for the inoculum for the next season. Parasitism of aphids is mostly observed in the form of mummies in colonies. In the Low Durance valley region, parasitism of diapausing larvae is low in both organic and conventional orchards (about 3%) but can reach high frequencies in untreated orchards (up to approx 80%). It is mostly caused by *Ascogaster quadridentata* (Brachonidaea), an hymenoptera specialist of Tortricidae, that accounts for 80% of parasitism. Other parasitoids are *Pristomerus vulnerator* and *Perilampus* spp. This last species may be an hyperparasite of *A. quadridentata*. *Trichomma enecator* was not observed under Mediterranean climates but it is very frequent northerly (Rosenberg 1934, Athanasov et al 1997, Diaconu et al 2000). First experiments indicate that these main parasitoid species increase their longevity when fed with nectar of flowering plants. Parasitism of the rosy apple aphids is mainly caused by *Ephedrus* spp. (Braconidae) in the Low Durance valley (Dib et al 2010). Parasitism of the wooly apple aphid is mainly caused by *Aphelinus mali* (Aphelinidae) (Lavandero et al 2011). This very specific parasitoid is the sole means of control of the wooly apple aphid in season in organic orchard in Europe.

8.2.2 PESTS AND BENEFICIALS IN OILSEED RAPE / WHEAT ROTATION SYSTEM

The area of Winter Oilseed Rape (*Brassica napus* L. - OSR) has increased over recent years, which makes it the second most important arable crop after wheat in France and Europe. The agronomic benefit for the oilseed rape/ wheat rotation systeme were detailed in Kirkegaard *et al* (1994)

Pollen beetle – Parasitoid system

In Europe, the Pollen beetle, *Meligethes aeneus*, is one of the major insect pests of OSR and its control has become a major concern as insecticide resistant populations increase (Detourne et al 2008, Thieme et al 2010). Following emergence from overwintering sites, adult pollen beetles migrate into OSR crops to feed on pollen and oviposit in buds thereby inflicting severe yield losses (Nilsson 1994). At the local scale, pollen beetle abundance and damage is affected by farming practices, including soil nitrogen availability and crop density (Valantin-Morison et al 2007), trap cropping (Cook et al 2006) and tillage (Rusch et al 2011). At the landscape scale, visual and odour cues affect the dispersal of pollen beetles, which are able to move several kilometers (up to 12 km in two days) from a release point to locate the host plant (Stechmann and Schütte 1976; Williams et al 2007). Landscapes with high proportions of semi-natural habitats tend to support lower populations of pollen beetle due to greater control by parasitoids (Thies et al 2003).

The role of natural enemies in regulating pollen beetle populations can be substantial, and thus present a promising component of integrated pest management solutions (Nilsson 2010). In particular, univoltine ichneumonid larval endoparasitoids of pollen beetle such as *Tersilochus heterocerus* may cause high mortality rates (Jourdheuil 1960, Ulber et al 2010). At field scales, the type and intensity of soil tillage used at sowing the crop following OSR can greatly influence the mortality of parasitoids (Nilsson 2010). Across landscapes, the rate of parasitism in pollen beetle larvae was positively influenced by landscape complexity (Thies and Tscharntke 2003). Surrounding OSR fields, in the previous year (OSRn-1), and their post-harvest soil tillage negatively impacted parasitism rates (Rusch et al 2011). At the largest scales (1500 m to 2000 m), parasitism rates of *T. heterocerus* were positively related to semi-natural habitats and negatively related to the proportion of OSR fields with conventional soil tillage in the previous year.

Aphid – Predator system

Aphids are among the main agricultural pests in temperate climates and in OSR, two species are frequently encountered: the cabbage aphid *Brevicoryne brassicae* and the peach-potato aphid, *Myzus persicae*. *Brevicoryne brassicae* is a polyphagous species that can develop on many species of the brassicaceae family including weeds and cultivated plants. *Myzus persicae* is still more polyphagous attacking hundreds of species of cultivated and uncultivated plants of various families. Landscape composition of these primary and secondary plant hosts directly influences the prevalence of these pests on the crop as well the field-to-field secondary spread. Preliminary studies in western France, on *R. padi*, have also suggested that colonization of cereal seedlings in autumn could depend on landscape openness (Gilabert *et al* unpubl.).

Aphid outbreaks are sporadic in space and time. This suggests that natural limitation of their population dynamics occurs frequently. Biological control of aphids is provided by a wide diversity of natural enemies including generalist (such as carabids, spiders and ladybirds) and more specialized (lacewings and hoverflies) predators, and specialized parasitoids, e.g. *Diaeretiella rapae* which frequently attacks both *B. brassicae* and *M. persicae*. Semi-natural habitat may provide alternative prey, complementary resources or overwintering sites for aphid natural enemies. For instance, flowering strips provide resources for hoverflies and lacewings, which are polliniphagous at the adult stage, while grass strips provide overwintering sites for predators such as carabids and spiders (beetle banks, MacLeod *et al* 2004). The hoverfly *Episyrphus balteatus* uses local forests and their edges during winter and summer (Sarthou *et al* 2005), and colonizes the crop mosaic only in spring (Arrignon 2007).

Weed – Seed predator system

Weeds are a common pest of OSR. OSR cultivation typically favors cruciferous species (Wahmhoff 2000) and problematic weeds, in general, due to the weaknesses of current herbicide programmes (Lutman et al 2009). The abundance of weed seeds in the soil seed bank of a field is related to agricultural management and may be associated with the history and sequence of crops grown over the previous 3 years (Bohan et al 2011a). Field margins often shelter higher diversity and abundance of weed species than the centre of cultivated fields and exchange and spillover of weed spcies between the field and boundary can occur in both directions (Marshall 1985). At the landscape level, weed species richness per field may be positively related to landscape complexity (field size, density of boundaries) (Roschewitz 1996), but this has not been detected in all situations and relatively little is known on the effect of landscape on weed abundance.

There is evidence that weeds can be partly regulated by predation of the weed seeds that become available on the soil surface (just after seed shed) and before seeds integrate the soil seed bank. Indeed, changes in the weed seedbank across the national scale were recently related to the abundance of seed-eating carabid beetles across a range of climatic and agronomic situations (Bohan et al 2011). Some seed-eating carabids are specialist (granivorous) but communities are often dominated by generalist (omnivorous) that appear to shift from animal prey in spring to weed seeds in the summer (Brooks et al 2011). Increased crop cover (i.e. annual crop at different stages or perennial vs. annual crops) seems to translate into increased predation rates (Meiss et al 2010). In addition, the landscape context has been shown to affect predation rates (Menalled et al 2000). As previously described for aphids, semi-natural habitats may affect richness and abundance of seed-eating carabids in adjacent production areas.

8.2.3 IMPACT OF AGRONOMIC PRACTICES ON IN-CROP BIODIVERSITY

The reduction of soil tillage and the utilization of a cover crop in orchards or in grain crops provide a more favorable environment for beneficial organisms (Jones et al, 1994). Soil tillage practices affect the soil biota and organism habitat of fields since Soil tillage practices affect organic matter composition, soil moisture and the structure of the soil surface (Holland, 2004). Several studies have shown that the accumulation of organic matter at the soil surface almost always leads to an increase in the diversity of generalist predators (ground beetles, spiders and rove beetles) (Hanna et al, 2003; Mathews et al, 2004; Schmidt et al, 2004; Pullaro et al, 2006). According to Landis et al (2000), the presence of decomposing organic matter at the surface of the soil provides the predators with alternative prey when there are no crop pests present in the plot. Although, the presence of sufficiently large amounts of residues after the harvesting of the crop creates an unfavourable environment for weed germination and establishment, tillage is an effective method of non-chemical weed control and no-till systems may suffer from increased weed infestation resulting in higher herbicide use. A way to cope with this problem is to implement a cover crop (sowing a second crop when harvesting the main one) in relay or permanently. The principal goal of cover crops is to control weeds, by replacing an unmanageable weed population with a manageable cover crop. This is accomplished by adjusting the phenology of the cover crop such that it occupies the available niches before they can be occupied by weed populations. As weeds and living mulch plants compete for the same resources, weeds can be suppressed by introducing living mulches into cropping systems (Teasdale et al, 2007). Undersown cover crops may decrease weed infestation in three ways (Phatak, 1992; Bastiaans et al, 2002): preventing weed seed germination and emergence, decreasing weed growth and development, and decreasing the number of seeds present in the weed seed bank in the soil by limiting seed recruitment and increasing seed predation. However, the studies which analyse this effect are still rare.

8.3. DESCRIPTION OF EXPERIMENTAL SITES

Description of the experimental trials for the different sites. Each column corresponds to one site that may contain 1 or 2 experimental systems. The first column describes the variables that will be managed in these experiments. The second column specifies the type of management planned.

	Crops	**Wheat/Oil seed rape rotation**				**Apple orchards**	
	Sites	**Versailles/**	**Villarceaux**	**Dijon**	**Angers**	**Gotheron**	**Avignon**

		Grignon					
Management of non crop habitats in field margins	Optimisation of wild flower strip species composition	x		x	x		
Management of non crop habitats in field			x			x	x
Crop habitat management	No till system	x		x			
Direct control measures in crop	Zero pesticides system or organic systems	x	x	x		x	
	Netting + low input systems					x	x

8.4. DESCRIPTION OF THE PARTNERS

8.4.1 PARTNER 1: PSH

Plantes et Systèmes de culture Horticoles - UR1115
(Horticultural Plants and cropping Systems) (https://www4.paca.inra.fr/psh)
The EPI (Ecology of Integrated Production) team from PSH will be involved in *PEERLESS*. EPI develops methods that improve the control of *Cydia pomonella* and *Dysaphis plantaginea* pests by their natural enemies using either landscape management (Dib et al 2009 ; Ricci et al 2009, 2011) or the facilitation of pest enemy populations within the orchard using an agro-ecological approach. Researchers of EPI have experience in spatial analyses at field and landscape scales (Lavigne et al 2010; Debras et al 2008; Veres et al 2012), in microsatellite markers development (Green et al 2001; Guerin et al 2004; Franck et al 2005; Jourdie et al 2009) and population genetics of both Hymenoptera (Cameron et al 2004; Franck et al 2001; 2004; Kraus et al 2007), Lepidoptera (Franck et al 2007) and *D. Plantaginea* (Guillemaud et al 2011) and their parasitoids (Lavantero et al 2011). PCR-RFLP tools to identify the main larval Hymenoptera parasitoids of *Cydia pomonella* in France (*Ascogaster quadridentata*, *Pristomerus vulnerator* and *Perilampus tristis*) have been developed as well as molecular tools to detect *C. pomonella* and *D. Plantaginea* in guts of arthropod predators (Boreau 2012; Boreau et al 2012).
Facilities for insect rearing, morphological identification; toxicological, biochemical and molecular experiments are available at the PSH unit:

- Insectarium with 6 different climatic chambers and several microscopes
- Laboratory for toxicological and biochemical analyse
- Biological molecular facilities at the LBM laboratory shared by INRA units at Avignon
- Experimental orchards
- GIS and voucher databases dedicated to study area "Basse Vallée de la Durance"

8.4.2 PARTNER 2: AGRONOMIE

Agronomy – UMR211

Agronomie at Grignon is devoted to the design and assessment of innovative and sustainable cropping systems in Europe, taking into account several crops and diverse biotic and abiotic factors. This team research has two main research activities: (1) design and assessment of cropping system at field scale and at landscape scale, (2) the analysis of crop-pests interaction at field level. The unit develops/uses a diversity of models, statistical methods and expert knowledge on various crops and also at the scale of the cropping system and landscape level. One of the activities is the analysis and modeling of the interaction of disease or pest and natural ennemies in different landscape pattern to identify the best cropping systems organisation and field margins management in landscapes (See model named Sippom and Mosaic Pest)

8.4.3 PARTNER 3: IGEPP

Institut de Génétique, Environnement et Protection des Plantes (IGEPP) – UMR 1349

UMR IGEPP (ex BiO3P) is a joint research unit including scientists from INRA Rennes, University Rennes 1 and Agrocampus Ouest. Its objective is to describe, understand and predict the functioning of plants, their associated organisms and the agroecosystems, in order to contribute to the improvement of new plant protection methods taking into account sustainability and environment safety, and aiming at low input agriculture development. Our proposal is held by the 'Ecology and Genetics of Insects' (EGI) team which is recognized for its research on insect evolution and ecology and was rated A + by AERES (2011). In this team, evolutionary biologists, ecologists, modellers, genomicists and bioinformaticians work together on integrated studies of insects' life-history traits including dispersal, reproductive mode, host specialization and of insects' community including interactions with plants, natural enemies and symbionts.
IGEPP is a very large unit and it has many facilities for insect rearing and experimentation (climatic chambers, glasshouses, field experiments) and for molecular analyses. It has a GIS dedicated to the study area "Zone Armorique" http://osur.univ-rennes1.fr/zoneatelier-armorique/

8.4.4 PARTNER 4: AGROECOLOGIE

UMR 1347 Agroécologie, Dijon

http://www4.dijon.inra.fr/osaepc/UMR-Agroecologie

The Agroecologie Research Unit (AE, Dijon) was created January 1st, 2012. In this unit, ecologists, agronomists, geneticists and medical scientists are involved in issues associated with the conception and the evaluation of agricultural systems that satisfy both food production and environmental criteria. The entire AE participants to the *PEERLESS* projects are members of the "Community ecology and sustainability of agricultural systems" team. This team studies the links between agricultural systems, functioning of communities and the agroecological services provided by these communities. The research studies consists in the experimentation of innovating crop systems, the observation of the modification of the weed flora and of their natural enemies both at the local and the landscape scale, and the development of models in order to predict weed flora in function of agricultural practices. In the recent years, the participants to the *PEERLESS* project were involved in several experimental designs (Integrated Crop Protection Network, "Réseau PIC") and study areas at the landscape scale (Fénay study site, network of undersown cover crops fields). Within these experimental or observational designs, researches on the biological regulation of the weed flora by granivorous insects has started, notably in the ANR Systerra ADVHERB project (2008-2012) which is coordinated by the AE unit.

8.4.5 PARTNER 5: BIOSP

UR 546 Biostatistique & Processus Spatiaux , Avignon
The Biostatistics and Spatial Processes Unit conducts research in theoretical and applied statistics and spatial and spatio-temporal modelling. Particular attention is devoted to applications related to the environment, ecology, epidemiology and population biology.
Subjects for applied research include:

- geostatistical modelling for spatialised environmental data,
- study of the spatial structuring of pest populations,
- analysis of the dispersion of the genes, seeds and/or pollen of various plants,
- the spread of plant epidemics and the detection of outbreaks of animal epidemics.

8.4.6 PARTNER 6: EP

UMR 210 Economie Publique - Avenue Lucien Brétignières, 78850 Thiverval-Grignon
(http://www4.versailles-grignon.inra.fr/economie_publique)
The Joint Research Unit in Public Economics is a research and teaching unit in applied economics in the fields of agriculture and the environment. It is a part of INRA's Social Sciences, Food, Agriculture and Environment Department.
The research focuses on environmental and public policy concerns in the agricultural and agribusiness sectors as well as on international trade. This research aims to develop methods of analysis, simulation models, and tools for reflection that can be used by economic policy makers and, more broadly speaking, by all social actors.
The Research Unit will collaborate to the project *PEERLESS* by providing its expertise on environmental and agricultural economics and policies, within its Environment, Energy and Public Policy research axis. This area of expertise includes work on global warming, environmentally-friendly agricultural practices, the valuation of non-food agricultural products, land-use, and biodiversity, as well as contractual and regulatory tools in this area of study.

8.5. CURRICULUM VITAE

8.5.1 PARTNER 1: PSH

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http://www4.paca.inra.fr/psh/Equipes-de-recherche/Ecologie-de-la-Production-Integree/Les-Personnes/Pierre-Franck
55 publications in peer-reviewed international journals or proceedings

Education & Professional experience

Since 2006: Researcher (CR1) at the ***INRA Laboratory «Plantes & Système de cultures Horticoles»*** - Avignon (France). Genetic and dynamic insect pests and their natural enemies in integrated production system.

2002-2005: Researcher (CR2) ***INRA-UAPV Laboratory «Ecologie des Invertébrés»*** - Avignon (France). Genetic structure of codling moth population in pest management integrated systems.

2001-2002: Post-doc at the ***Centre de Biologie et de Gestion des Populations*** - Prades-le-Lez (France). Population genomics of *Apis mellifera* intra-specific hybrid.

2000-2001: Post-doc at the ***School of Biological Sciences*** - University of Sydney- Genetic architecture within and among species in a complex of stingless bee species [*Trigona* (*Heterotrigona*)].

1996-1999: PhD at the ***INRA laboratory «Modélisation & Biologie Evolutive»*** - Montpellier (France). Analysis of the genetic structures within honeybee colonies and populations and study of evolutionary implications. 1st class honor PhD with the jury's congratulation (National School of Agronomy at Montpellier, ENSAM).

Five selected publications

Lavandero B, Figueroa CC, **Franck P**, Mendez A (2011) Estimating gene flow between refuges and crops: A case study of the biological control of *Eriosoma lanigerum* by *Aphelinus mali* in apple orchards. PloS ONE 6: e26694.

Guillemaud T, Blin A, **Simon S**, Morel K, **Franck P** (2011) Weak spatial and temporal population genetic structure in the rosy apple aphid, *Dysaphis plantaginea*, in French apple orchards. PloS ONE 6: e21263

Franck P, Ricci B, Klein EK, Olivares J, Simon S, Cornuet JM, **Lavigne C** (2011) Genetic inferences about the population dynamics of codling moth females at a local scale. Genetica 139: 949-960.

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Cornuet, J.-M., Excoffier, L., **Franck, P.**, Estoup, A., 2009. Bayesian Inference under Complex Evolutionary Scenarios using Microsatellite Markers: Multiple Divergence and Genetic Admixture Events in the Honey Bee, *Apis Mellifera*. In: Mahoney, C.L., Springer, D.A. (Eds.), Genetic Diversity. Nova Sciences Publishers, Hauppauge, pp. 229-246.

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Since July 1st 2008: Researcher (CR2), Plantes et Systèmes de culture Horticoles, INRA, France
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2003-2006: PhD thesis in Automatic Control and Industrial Information Technology, Ecole Centrale de Lille and Université des sciences et technologies de Lille.

Main research interests:

Current:

Currently I am junior scientist in the team Integrated horticultural crop production. My research focus is on the model-based design of integrated horticultural production systems. The developed approaches are mainly originated from artificial intelligence and multicriteria decision making. They aim to formulate the design of integrated horticultural production systems as a multiobjective optimization problem and to propose efficient algorithms able to resolve this kind of optimization problems. This work uses the biotechnical models developed by my colleagues. These models describe either the interactions between plants, pests, and natural enemies under the effect of cultural practices or the interactions between genotypes, environments and cultural practices. Our short-term objective is to be able to propose effective and realizable technical procedures that satisfy many antagonist criteria and respect some biotic and abiotic constraints.

Past:

Postdoc: During my postdoctoral stay at Université du Littoral Côte d'Opale and GDF, I had worked on the optimal design and dimensioning of hydrogen transmission distribution pipeline networks. The design problem includes the topology determination and the dimensioning problem. We developed new solution method that simultaneously looks for the least cost topology of the network and for the optimal diameter of each pipe. These two problems were generally solved separately in the literature. The proposed approach was applied to the case of development of future hydrogen pipeline networks on several urban areas in Europe and the obtained results demonstrated the effectiveness of this approach compared to the classical ones. The networks were modeled by means of graphs and the proposed approach was based on the nonlinear optimization techniques. This work was realized with the collaboration of Gaz de France, Total, and The French petrol institute (IFP) in the framework of the EcoTransHy project.

Publications

B. Quilot-Turion, MM. Ould Sidi, A. Kadrani, N. Hilgert, M. Génard, F. Lescourret. *Optimization of genetic parameters of the 'Virtual Fruit' model to design peach ideotypes for sustainable production systems.* European Journal of Agronomy (in press, doi:10.1016/j.eja.2011.11.008).

MM. Ould Sidi and F. Lescourret. *Model-based design of innovative cropping systems: state of the art and new prospects*. Agronomy for sustainable development. Volume 31, Issue 3 (2011), Page 571-588.

Mohamed-Mahmoud Ould-Sidi, Bénédicte Quilot-Turion, Antoine Rolland. *Multicriteria sorting methods to select virtual peach ideotypes*. Submitted to Journal of Multi-Criteria Decision Analysis.

J. André, S. Auray, J. Brac, D. De Wolf, G. Maisonnier, MM. Ould Sidi, A. Simonet. *Optimal design and dimensioning of Hydrogen transmission pipeline networks*. European journal of Operations Research (in revision).

D. De Wolf, MM. Ould Sidi, J. André, A. Simonnet, G. Maisonnier, J. Brac. *Optimal design and dimensioning of Hydrogen transmission distribution pipeline networks*. HEC Discussion Paper 2009 03/01, Mars 2009.

Claire LAVIGNE, 43, Female.
Senior scientist (directrice de recherche), HDR
UR1115, Plantes & Systèmes de culture Horticoles INRA, F-84914 AVIGNON Cedex 9
claire.lavigne@avignon.inra.fr,

Education & Professional experience

Since 2005:	Senior scientist (DR) at the ***INRA Lab. «Plantes et Système de cultures Horticoles»***-Avignon (France). In charge of team 'Ecology of integrated Production' (approx. 25 pers.). Landscape ecology of pests and pest ennemies.
1998-2005:	Assistant professor: University Paris-Sud, Orsay, Laboratory Ecologie, Systématique, Evolution - Paris (France). Landscape scale pollen dispersal; co-existence of GM and conventional crops.
1997-1998:	Assistant professor : University Paris-Sud, Orsay, Laboratory Institut de Biotechnologie des Plantes – Paris (France). Epidemiology of anthracnosis in *Phaseolus vulgaris* populations.
1995-1996:	Post-doc at the Institute of environmental sciences, University of Zurich, Switzerland. Genetic variability in plant responses to climate change.
1991-1994:	PhD at the University Paris-Sud, Orsay, Laboratory Ecologie, Systématique, Evolution - Paris (France). Ecological impacts of GM crops.
1990-1991:	**Post graduate diploma** in **Ecology** - University of Paris XI
1988-1991:	Engineering school of agronomy, ENSA-Montpellier.

38 publications in peer-reviewed international journals

Five selected publications

Veres A., **Petit, S.**, Conord C., **Lavigne C**. 2012. Does landscape composition affect pest abundance and their control by natural enemies? A review. Agriculture, Ecosystems & Environment. Online.

Boreau C., **Lavigne C.**, Ricard J.M., **Franck P.**, Bouvier J.C., Garcin A., Symondson W.O.C. 2012. Predation by generalist predators on the codling moth vs. a closely related emerging pest the oriental fruit moth: a molecular analysis. *Agricultural and Forest Entomology*

Lavigne C., **Ricci B**., **Franck P**., Senoussi R. 2010. Spatial analyses of ecological count data: a density map comparison approach. *Basic and Applied Ecology* **11** : 734-742.

Le Ber F., **Lavigne C.,** Adamczyk K., Mari J.-F., Angevin F., Monod H., Colbach N. 2009. Neutral modelling of agricultural landscapes by tessellation methods. Application for gene flow simulation. *Ecological Modelling*, 220:3536-3545.

Lavigne C., Klein E.K., Mari J.-F., Le Ber F., Adamczyk K., Monod H., Angevin F. 2008. How do genetically modified (GM) crops contribute to background levels of GM pollen in an agricultural landscape ? *Journal of Applied Ecology*. 45:1104-1113.

Jérôme OLIVARES, 36, Male
Technician
PSH
Tel: 0432722824
Jerome.olivares@avignon.inra.fr

Education

1992 Baccalauréat F7 option "technics of laboratories"

Technics: organic chemistry, dilutions, preparation of biological buffers….

1994 Diplome of the Technological University Institute of Montpellier option "biological analyses"

Technics: enzymology, pharmacology, manipulation of animals of laboratory cells culture, bacteriology.

Professionnal experiences

1994 microbiologist technician at the laboratory "microbiologie test service", Carros, France
Technics: microbiology, validation of antiseptic products.

1997 Immunologist technician at the university laboratory of immunology of Professor Bouix, Montpellier, France.
Technics: manipulation of animals of laboratory, cells culture, production and purification of monoclonal antibodies from rabbit and mice.

2004 Molecular biologist technician at the "Technical tray of molecular biology" of I.N.R.A. of Avignon, France.
PCR, Polyacrylamide gels, silver staining, analyses of sequences of DNA, manipulation of insects, extraction and purification of DNA, analyses of microsatellite loci on sequencer LiCor 4200, enzymatics tests, detection of the Knock down resistance mutation and the acetylcholinesterase resistance mutation in the codling moth *Cydia*

pomonella on sequencer LiCor 4200. Amplification and analyses of sequences of mitochondrial DNA.

Selected Publications

Franck P, Reyes M, **Olivares J**, Sauphanor B (2007) Genetic architecture in codling moth populations: comparison between microsatellite and insecticide resistance markers. Molecular Ecology 16, 3554-3564.

M Reyes, P Franck, PJ Charmillot, C Ioriatti, **J Olivares**, E. Pasqualini, B Sauphanor. (2007). Diversity of insecticide resistance mechanisms and spectrum in European populations of the codling moth, Cydia pomonella. Pest Management sci 63:890-902

Franck P, Ricci B, Klein EK, **Olivares J,** Simon S, Cornuet JM, Lavigne C (2011) Genetic inferences about the population dynamics of codling moth females at a local scale. Genetica 139: 949-960.

8.5.2 PARTNER 2: AGRONOMIE

Muriel Valantin-Morison, CR1, 41 ans

Dr Muriel Valantin-Morison obtained her Master's degree in plant's developmental biology at Pierre and Marie Curie University (Paris) in 1994. She did her PhD and a post-doc at INRA Avignon on melon quality modelling (1994-1999). She started working as a research scientist in UMR Agronomie in 2000. Her aim is to develop methods for the design of pesticide-free crop management in winter oilseed rape: she first completed a regional diagnosis on organic winter oilseed rape and a diagnosis on the impact of cropping systems and semi-natural habitats on natural regulation of insect pests in oilseed rape fields. The resulting prototypes of innovative crop management plans were then tested in a network of farmers' fields. Since 2007, she has been working on the effects of cropping practices in the field and in the surrounding landscape as well as the proportion and location of semi-natural habitats on insects' dynamics and nuisibility in winter oilseed rape. She supervised the work of several PhD students and post-doctoral researchers who helped her to build a crop-pest-parasitoid model named "Mosaic Pest", whose objective is to support the design of cropping systems arrangements in a landscape to enhance natural control of insect pests.

Selected publications

Valantin-Morison M., Meynard JM., Doré T. 2007. Crop management and environment effects on insects in organic winter oil seed rape (WOSR) in France. Crop protection 26 : 1108-1120

Valantin-Morison M., Meynard J.M., 2008. Yield variability of Organic Winter Oil Seed Rape (WOSR) in France: a diagnosis on a network of farmers fields, Agronomy for Sustainable Development, 28 (2008) DOI: 10.1051/agro:2008026

Rusch A., Valantin-Morison M., Sarthou J-P, Roger-Estrade J. 2010. Biological Control of Insect Pests in AgroecosystemsEffects of Crop Management, Farming Systems, and Seminatural Habitats at the Landscape Scale: A Review. Dans *Advances in Agronomy*, 109:219-259. Elsevier. http://linkinghub.elsevier.com/retrieve/pii/B9780123850409000062.

Rusch A., Valantin-Morison M., Sarthou J-P, Roger-Estrade J. 2011. Local and landscape determinants of pollen beetle (Meligethes aeneus F.) abundance in overwintering habitats. Agriculture and Forest Ecology DOI: 10.1111/j.1461-9563.2011.00547.x

Rusch A., Valantin-Morison M., Sarthou J-P, Roger-Estrade J. 2011. « Multi-scale effects of landscape complexity and crop management on pollen beetle parasitism rate ». *Landscape Ecology* 26 : 473-486. doi:10.1007/s10980-011-9573-7.

Médiène S., Valantin-Morison M., Sarthou J-P, Stéphane de Tourdonnet S., Gosme M., Michel Bertrand, Roger-Estrade J. Aubertot J-N, Rusch A., Motisi N., Pelosi C., Doré T. Agroecosystem management and biotic interactions. 2011. A review. Agronomy for Sustainable Development. DOI 10.1007/s13593-011-0009-1

Valantin-Morison M., Meynard J-M. 2011. A conceptual model to design prototypes of crop management : a way to improve organic Winter Oilseed Rape performance in a survey in farmers' fields. In Crop Management, ed In TECH, ISBN 978-953-307-646-1.

Marie Gosme, CR2, 33 years

Dr Marie Gosme has an engineering degree from the National Superior School of Agronomy of Rennes (2004), she then did her PhD at INRA Rennes on spatio-temporal modelling of soil-borne plant diseases (2004-2007) and subsequently worked on epidemiological and evolutionary models at the University of Cambridge, UK (2007-2008). She then joined the Agronomy team at INRA Grignon in order to work on the interactions at the landscape scale between crops under different cropping systems and non-crop habitats. She completed a survey of farmer's cropping practices in a small region, and combined it with observations of pests (sensu lato) in a sample of wheat fields in order to quantify the effects of cropping practices in the field and in the surrounding fields as well as landscape composition in terms of crops and semi-natural habitats on aerial diseases, aphids and weeds. At the same time, she is developing a generic model of population dynamics at the landscape scale that takes into account the effect of cropping practices, predation and dispersal. She also takes part in a European project (SOLIBAM) that aims at developing methods for breeding and crop management adapted to organic farming. In this project, she works more specifically on the interaction between the management of field margins and the type of cultivar on aphid natural control by parasitoids and carabid beetles.

Selected publications

Gosme, M., Lucas, P., 2009. Cascade: an epidemiological model to simulate disease spread and aggregation across multiple scales in a spatial hierarchy. Phytopathology 99, 823–832.

Gosme, M., Suffert, F., Jeuffroy, M.-H., 2010. Intensive versus low-input cropping systems: what is the optimal partitioning of agricultural area in order to reduce pesticide use while maintaining productivity? Agricultural Systems 103, 110–116.

Médiène, S., Valantin-Morison, M., Sarthou, J.-P., de Tourdonnet, S., Gosme, M., Bertrand, M., Roger-Estrade, J., Aubertot, J.-N., Rusch, A., Motisi, N., Pelosi, C., Doré, T., 2011. Agroecosystem management and biotic interactions: a review. Agronomy for Sustainable Development 31, 491–514.

Gosme, M., de Villemandy, M., Bazot, M., Jeuffroy, M.-H., 2012. Effect of organic farming in the field and in neighbouring fields on aphids, weeds and aerial diseases of wheat. submitted to Agriculture, Ecosystems, Environment.

Vinatier, F., Gosme, M., Valantin-Morison, M., 2012. Testing IPM strategies on a tritrophic system at landscape scale using Mosaic-Pest model. en cours de rédaction.

8.5.3 PARTNER 3: IGEPP

Manuel PLANTEGENEST, 47, Male.
Lecturer (Maître de Conférences), HDR
Research Unit : **UMR 1349 IGEPP « Institut de Génétique, Environnement et Protection des Plantes »**
manuel.plantegenest@agrocampus-ouest.fr

38 publications in peer-reviewed international journals

Education & Professional experience

since 1995 Maître de Conférences in quantitative ecology at Agrocampus Ouest, Centre de Rennes, UMR IGEPP

1992 - 1995 PhD thesis in the "insect team" of the UMR BiO3P in INRA Rennes on the development of a decision support system for crop protection based on the modelling of a cereal aphid population dynamics

Five selected publications

Peccoud J., Ollivier A., **Plantegenest, M.** & Simon, J.C. (2009) A continuum of genetic divergence from sympatric host races to species in the pea aphid complex. *PNAS*. 106, 7495-7500.

Geiger, F., Bengtsson, J., Berendse, F., Weisser, W.W., Emmerson, M., Morales, M.B., Ceryngier, P., Kindlmann, P., Liira, J., Tscharntke, T., Winqvist, C., Eggers, S., Bommarco, R., Pärt, T., Bretagnolle, V., **Plantegenest, M.**, Clement, L.W., Dennis, C., Palmer, C., Oñate, J.J., Guerrero, I., Hawro, V., Ameixa, O., Rajchard, J., Aavik, T., Thies, C., Flohre, A., Hänke, S., Fischer, C., Inchausti, P. (2010) Persistent negative effects of pesticides on biodiversity and biological control potential on farmland. *Basic and Applied Ecology*. 11, 97-105.

Fabre, F., **Plantegenest, M.**, Hullé, M., Dedryver, C.A., Rivot, E. (2010) Hierarchical Bayesian Modelling of plant colonisation by winged aphids: Inferring dispersal processes by linking aerial and field count data. *Ecological Modelling*, **221**(15), 1770-1778.

Violle, C., Bonis, A., **Plantegenest, M.**, Cudennec, C., Damgaard, C., Marion B., Le Coeur, D., Bouzillé, J.-B. (2011) Plant traits capture species richness and coexistence mechanisms along a disturbance gradient. *Oikos*, **120**(3), 389-398.

Derocles, S.A.P., **Plantegenest, M.**, Taberlet, P., Simon, J.C., Le Ralec, A. (2012) A universal method for the detection and the identification of Aphidinae parasitoids within their aphid hosts. *Molecular Resources*, in press.

Amin BISCHOFF, 46, Male.
Lecturer (Maître de Conférences), HDR
Research Unit : **UMR 1349 IGEPP « Institut de Génétique, Environnement et Protection des Plantes »**
armin.bischoff@agrocampus-ouest.fr
http://www.agrocampus-ouest.fr/infoglueDeliverLive/fr/agrocampus-ouest/organisation/departements/sciences-biologiques/armin-bischoff

76 publications in peer-reviewed international (17) and national journals (11) or conference proceedings (48)

Education & Professional experience

since 2008	Maître de Conférences in plant ecology at Agrocampus Ouest, Centre d'Angers, INHP (Institut National d'Horticulture et de Paysage), UMR IGEPP
2006-2008	External lecturer in plant ecology at the University of Halle (Germany), Institute of Geobotany and ecological consulting (nature conservation and organic farming)
2001 - 2006	Researcher at the University of Fribourg (Switzerland), Unit of Ecology and Evolution; Plant Ecology Group; scientific coordination of two projects on intraspecific differentiation of plant populations, the choice of seed origin in ecological restoration and effects on herbivorous insects
1998 - 2001	Postdoc at the UFZ Centre of Environmental Research Halle-Leipzig (Germany) in two projects on ecological restoration of plant biodiversity
1997 - 1998	Research associate at the University of Halle (Germany)
1992 - 1996	PhD thesis at the University of Halle (Germany) on population and vegetation dynamics of weed communities following a reduction in land use intensity

Five selected publications

Bischoff, A. & Trémulot, S. (2011) Genetic differentiation and adaptation of plant populations: how important are related herbivores. Oecologia 165, 971–981.

Bischoff, A., Steinger, T. & Müller-Schärer, H. (2010) The effect of plant provenance and intraspecific diversity on the fitness of four plant species used in ecological restoration. Restoration Ecology 18, 338-348.

Bischoff, A. & Warthemann, G. & Klotz, S. (2009) Re-colonisation of floodplain grasslands – the importance of abiotic conditions and source populations. Journal of Applied Ecology 46, 241-249.

Cremieux, L., Bischoff, A., Smilauerova, M., Lawson, C., Mortimer, S., Dolezal, J., Lanta, V., Edwards, A., Brooks, A., Tscheulin, T., Macel, M., Leps, J., Steinger, T. & Müller-

Schärer, H. (2008). Potential contribution of natural enemies to patterns of local adaptation in plants. New Phytologist 180, 524-533.

Bischoff, A., Crémieux, L., Smilauerova, M., Lawson, C., Mortimer, S., Dolezal, J., Lanta, V., Edwards, A., Brooks, A., Macel, M., Leps, J., Steinger, T. & Müller-Schärer, H. (2006) Detecting local adaptation in widespread grassland species – the importance of scale and local plant community. Journal of Ecology 94, 1130-1142.

Yann TRICAULT, 40, Male.
Lecturer (Maître de Conférences)
Research Unit : **UMR 1349 IGEPP « Institut de Génétique, Environnement et Protection des Plantes »**
yann.tricault@agrocampus-ouest.fr

24 publications in peer-reviewed international journals (9) and conference proceedings (15)

Education & Professional experience

Since 2009	Lecturer in ecology and plant protection at **Agrocampus-Ouest, Centre d'Angers INHP** (Institut National d'Horticulture et de Paysage, France) ; current project on landscape ecology and the conservation of natural enemies of insect pests.
2006-2009	Researcher at the joint research unit **Biologie et Gestion des Adventices** ('BGA', Dijon, France); three projects on the evaluation of coexistence between GM and non GM crops with simulation models of transgene dispersal at landscape scale.
2001-2004	Postdoc at the **laboratory of entomology of WUR** (Wageningen University and Research center, The Netherlands) ; two projects on biological control modelling (host-parasitoid population dynamics).
2000	PhD thesis at the **Research Institute on Insect Biology** ('I.R.B.I.', Tours, France) ; Modelling of insect pest population dynamics and biological control.

Five selected publications

Colbach N., Chauvel B., Darmency H. & Tricault Y. 2011. Sensitivity of weed emergence and dynamics to life-traits of annual spring-emerging weeds in contrasting cropping systems, using weed beet (Beta vulgaris ssp. vulgaris) as an example. Journal of Agricultural Science, 149, 679–700

Tricault Y., Fealy R., Colbach N. & Mullins E. 2011. Towards an optimal management regime to facilitate the coexistence of GM herbicide tolerant and non-GM oilseed rape. European Journal of Agronomy, 34, 26–34

Colbach, N, Darmency, H, & Tricault, Y (2010) Identifying key life-traits for the dynamics and gene flow in a weedy crop relative: Sensitivity analysis of the GENESYS simulation model for weed beet (Beta vulgaris ssp vulgaris). Ecological Modelling 221, 225-237

Tricault Y, Darmency H & Colbach N (2009) Identifying key components of weed beet management using sensitivity analyses of the GENESYS-BEET model in GM sugar beet. Weed Research 49, 581-591.

Sester M, Tricault Y, Darmency H & Colbach N (2008) GeneSys-Beet: A model of the effects of cropping systems on gene flow between sugar beet and weed beet. Field Crops Research 107, 245-256.

Sylvain POGGI, 39, Male.
Research Scientist (Chargé de Recherche)
Research Unit: **UMR 1349 IGEPP « Institut de Génétique, Environnement et Protection des Plantes » (Rennes, France)**
sylvain.poggi@rennes.inra.fr

4 publications in peer-reviewed international journals (2 in ecological/epidemiological modelling), 1 more submitted publication, 12 communications at international conferences (5 in epidemiology or theoretical biology)

Education & Professional experience

Since 2008	Research Scientist at INRA (Rennes)
2007 – 2008	Senior Research Engineer at PDF SOLUTIONS, Paris / Montpellier / San Jose, USA (advanced algorithmic developments for process control)
2000 - 2007	Research Engineer at ALCTRA, Paris (physics, signal processing, statistical modelling)
1990 – 2000	Lecturer (ATER), University of Le Mans
1996 – 2000	PhD thesis in the Institute of Acoustics and Vibration, University of Le Mans (physics, signal processing)

Five selected publications

Motisi, N., **Poggi, S.**, Filipe, J.A.N., Lucas, P., Doré, T., Montfort, F., Gilligan, C.A.and Bailey, D.J. Epidemiological analysis of the effects of biofumigation for biological control of root rot in sugar beet. *Plant Pathology*, 2012 (to appear)

Hamelin, F.M., Castel, M., **Poggi, S.**, Andrivon, D. and Mailleret, L. Seasonality and the evolutionary divergence of plant parasites. *Ecology* 92 (12):2159-2166, 2011.

Montfort, F., **Poggi, S.**, Morliere, S., Collin, F., Lemarchand, E. and Bailey, D.J. Opportunities to reduce Rhizoctonia solani expression on carrots by biofumigation with Indian mustard. In *Acta Horticulturae*, edited by C. Hale, 2011.

Poggi, S., Deytieux, V., Neri, F., Bates, A., Otten, W., Gilligan, C.A., Bailey, D.J. Thresholds for the invasive spread and control of soil-borne disease in plant propagation. *10th International Epidemiology Workshop*, Geneva (USA), 2009.

Gazengel, B., **Poggi, S.** and Valière, J.C. Evaluation of two acquisition and signal processing systems for measuring acoustic particle velocities in air by means of laser Doppler velocimetry, *Meas. Sci. Technol*. 14, pp. 2047-2064, 2003.

Nicolas PARISEY, 32, Male.
Research Engineer (Ingénieur de Recherche)
Research Unit : **UMR 1349 IGEPP « Institut de Génétique, Environnement et Protection des Plantes »**
nparisey@rennes.inra.fr

5 publications in peer-reviewed international journals, 4 more submitted publications and 10 communications in international computer science conferences.

Education & Professional experience

Since 2009	Research Engineer in quantitative ecology at UMR IGEPP
2007 – 2009	Lecturer (ATER), University of Bordeaux
2003 – 2007	PhD thesis in the 'Signal Processing' team of the main Computer Science laboratory of Bordeaux (LaBRI) on modelling mitochondrial redox pathways.

Five selected publications

The loneliness of the electrons in the bc1 complex. Ransac S., Parisey N. and Mazat J.-P. (2008) BBA-Bioenergetics. 1777, 1053-1059.

Investigating oxido-reduction kinetics using protein dynamics. **Parisey N.** and Beurton-Aimar M. (2009) Journal of Biological Physics and Chemistry. *9 (1), 27-35.*

Delayed setting of the photoperiodic response in recombinant clones of the aphid species Sitobion avenae F. Dedryver, C.-A., Le Gallic J.F., Maheo F., **Parisey N.**, Tagu D. *Ecological Entomology* (accepted)

Multiscale analysis of flying insect dispersion in fragmented landscape. Ciss M., **Parisey N.**, Dedryver C.-A., Pierre J.S. *Ecological Informatics* (submitted)

The response of an insect per capita growth rate to temperature and host plant phenology: estimation from field data. Ciss M., **Parisey N.**, Fournier G., Dedryver C.-A., Pierre J.S. *Ecological Modelling* (submitted)

8.5.4 PARTNER 4: AGROECOLOGY

Ricci, Benoît. 31 years old.
Current situation:
Junior Scientist (Chargé de Recherche) at INRA. Agroécologie.
Cursus:

2003: Engineer degree in Agronomy (Specialization in country planning and environment, Montpellier Supagro)

2004: Master degree in Biology, Evolution, Ecology (Montpellier Supagro - University of Montpellier)

2006: Master degree in Geographical Information Science (University of Marne-la-Vallée - Ecole Nationale des Sciences Géographiques)

2009: PhD. In Agronomy (University of Avignon)

- Professional Experience:

2006-2009: PhD Student at PSH, INRA, Avignon

2009-2011: Post-doctoral position at Eco-Innov, INRA, Grignon

2011- present: Researcher at INRA, Dijon

Five selected publications:

Monteiro L.B., Ricci B., Franck P., Lavigne C., Toubon J.F., Sauphanor B. (2012) Predation of codling moth eggs is affected by pest management practices at orchard and landscape levels. Agriculture Ecosystems & Environment, in press

Franck P., Ricci B., Klein E.K., Olivares J., Simon S., Cornuet J.M., Lavigne C. (2011) Genetic inferences about the population dynamics of codling moth females at a local scale. Genetica, 139:949-960

Ricci B., Franck P., Bouvier J.C., Casado D., Lavigne C. (2011) Effects of hedgerow characteristics on intra-orchard distribution of larval codling moth. Agriculture Ecosystems & Environment, 140:395-400

Lavigne C., Ricci B., Franck F., Senoussi R. (2010) Spatial analyses of ecological count data: A density map comparison approach. Basic and Applied Ecology, 11:734-742

Ricci B., Franck P., Toubon J.F., Bouvier J.C., Sauphanor B., Lavigne C. (2009) The influence of landscape on insect pest dynamics: a case study in southeastern France. Landscape Ecology, 24:337-349

Sandrine Petit, Female, 42 years old

Education :

- 2007 - Habilitation HDR- Spatial structures and levels of biological diversity in agricultural landscapes. Rennes University, France
- 1994 - PhD thesis - Metapopulations in hedgerow networks: spatial analysis and diffusion. Rennes University, France
- 1991 – DEA

Positions held :

- 2012 Deputy head of UMR Agroécologie
- 2009 Deputy head of the UMR BGA
- 2007 DR2 INRA Dijon
- 1999-2007 Senior scientist at the Centre for Ecology and Hydrology (NERC) (UK)
- 1998 Post-doctoral Louvain la Neuve University (BE)
- 1997 CNRS Rennes University
- 1996 Post-doctoral Stirling University (UK)

Publications

46 publications in international journals

Most relevant recent publications:

<u>Petit, S</u>., Alignier, A., Colbach, N., Joannon, A., Thenail, C. (in press) *Weed dispersal by farming activities across spatial scales: a review.* Agronomy for Sustainable Development

Cordeau, S., Petit, S., Reboud, X., Chauvel, B. (2012) Sown grass strips harbour high weed diversity but decrease weed richness in adjacent crops. Weed Research 52, 88-97

Brooks, DR, Storkey J, Clark, SJ, Firbank LG, Petit, S. & Woiwod IP. (2011). *Trophic links between functional groups of arable plants and beetles are stable at a national scale*. Journal of Animal Ecology 81, 4-13.

Veres, A., Petit, S., Conord, C., Lavigne, C. (2011) *Does landscape composition affect pest abundance and their control by natural enemies ? A review*. Agriculture, Ecosystems & Environment 138, 10-16.

Bohan, D.A., Boursault, A., Brooks, D. and Petit, S. (2011). *National-scale regulation of the weed seedbank by carabid predators*. Journal of Applied Ecology 48, 388-398.

Petit, S., Boursault, A., Le Guilloux, M., Munier-Jolain, N. & Reboud, X. (2011). *Weeds in agricultural landscapes : a review*. Agronomy for Sustainable Development 31, 309-317.

Meiss, H., Le Lagadec, L., Munier-Jolain N., Waldhardt, R. & Petit, S. (2010) *Weed seed predation increases with vegetation cover in arable fields.* Agriculture, Ecosystems & Environment 138, 10-16.

Gaba, S., Chauvel, B., Dessaint F., Bretagnolle, V. & Petit, S. (2010) *Weed species richness in winter wheat increases with landscape heterogeneity*. Agriculture, Ecosystems & Environment, 138, 318-323.

David A. BOHAN, 43, Male.
INRA International Fellow, (HDR equivalence)
Research Unit : **UMR 1347** Agroécologie
David.Bohan@dijon.inra.fr

57 publications in peer-reviewed international journals

Education & Professional experience

since 2011	INRA International Fellow, INRA-Dijon, UMR 1347 Agroécologie, 17 rue Sully, BP 86510, 21065 Dijon cedex.
2001 - 2010	Principal Investigator, Department of Plant and Invertebrate Ecology, Rothamsted Research, Rothamsted, AL5 2JQ. UK.
1997 - 2001	Post-doctoral Research Scientist, IACR-Long Ashton Research Station, Department of Agricultural Sciences, University of Bristol, Long Ashton, Bristol BS41 9AF. UK.
1995 - 1996	Postdoc at DEEB, University of Glasgow, Glasgow, G12 8QQ. UK.
1992 - 1995	PhD thesis at the Imperial College, London on 'Modelling the infection dynamics of *Steinernema feltiae*'

last five publications

Bohan DA, Haughton AJ (2012) Effects of local landscape richness on in-field weed metrics across the Great Britain scale. Agriculture, Ecosystems and Environment. doi:10.1016/j.agee.2012.03.010.

Tamaddoni-Nezhad A, **Bohan D**, Raybould A, Muggleton S (2012) Machine Learning a Probabilistic Network of Ecological Interactions. in Lecture Notes in Computer Science, Springer.

Bohan DA, Caron-Lormier G, Muggleton S, Raybould A, Tamaddoni-Nezhad A (2011) Automated Discovery of Food Webs from Ecological Data Using Logic-Based Machine Learning. PLoS ONE, 6: e29028. doi:10.1371/journal.pone.0029028.

Bohan DA, Boursault A, Brooks DR, Petit S (2011) National-scale regulation of the weed seedbank by carabid predators. Journal of Applied Ecology, 48, 888–898 doi: 10.1111/j.1365-2664.2011.02008.x

Bohan DA, Powers SJ, Champion G, Haughton AJ, Hawes C, Squire G, Cussans J, Mertens SK (2011) Modelling rotations: can crop sequences explain arable weed seedbank abundance? Weed Research 51, 422–432.

8.5.5 PARTNER 5: BIOSP

8.5.6 PARTNER 6: ECONOMIE PUBLIQUE

Martinet, Vincent. 32 years old.

- Current situation: Junior Scientist (Chargé de Recherche) at INRA. Public Economics.
- Cursus:

2002: Engineer degree in Agronomics (AgroParisTech)
2002: Master degree in Environmental and Resource Economics (ParisTech)
2005: PhD. In Economics (University Paris X Nanterre) – Highest honors

- Professional Experience:

2002-2005: PhD Student at THEMA, University of Paris X Nanterre
2005-2007: Post-doctoral position at IFREMER (Brest, France)
2007- present: Researcher at INRA
2010: Visiting fellow at GERAD (HEC Montreal, Canada) – 8 months

- Publications:

1. `Biological conservation in dynamic agricultural landscapes: effectiveness of public policies and trade-offs with agricultural production' (with F. Barraquand), 2011, *Ecological Economics* 70, p.910-920.
2. `A characterization of sustainability with indicators', 2011, *Journal of Environmental Economics and Management* 61, p.183-197.
3. `Hare or Tortoise? Trade-offs in recovering sustainable bioeconomic systems' (with O. Thebaud and A. Rapaport), 2010, *Environmental Modeling and Assessment* 15(6), p.503-517.

4. *Economic theories and Sustainability: What can we preserve for future generations?*, Routledge, Oxon (United-Kingdom), programmed to appear in May 2012. (ISBN-10: 0415544777)
5. `A multidisciplinary modelling approach to understand the effects of landscape dynamics on biodiversity' (with C. Gaucherel, V. Bretagnolle et al), 2010, International Conference on Integrative Landscape Modelling ; 2010/02/03-05 ; Montpellier. 10 p.

Publications in international journals: 12.

- Prices, distinctions:

PhD thesis award: Louis Forest, Chancellerie des Universités de Paris (Best Economics PhD in 2005)
OECD Best paper in Fishery Policy at IIFET 2008 – Honorable mention
Prime d'Excellence Scientifique (2011-2014)

8.6. PROFILES FOR NON-PERMANENT SCIENTIFIC POSITIONS

8.6.1 PARTNER PSH

Postdoc, year 2 and 3, tasks 5 and 6, PSH Avignon/IGEPP Rennes, ANR funding (15 months)
The model-based design of integrated production systems is increasingly studied as a typical multi-criteria optimization problem. Indeed evaluation of the systems designed requires both the integration of economic, social and environmental objectives, as well as the treatment of the conflicting aspects of these objectives in relation to the opinions of the individuals involved in the design process. Solving such optimization problems requires finding compromise solutions consisting of trade-offs between the antagonist performance criteria that reflect the preferences of the decision-maker. In order to propose alternative crop systems and viable landscape design, we must first understand how inter-specific interactions and population dynamics of pests and their natural enemies can be controlled by spatio-temporal landscape patterns. Afterwards, we will investigate the necessary trade-off between the pest control ability of these patterns and their economical viability.
The post-doc will (i) design population dynamics models on weed and insects pests and their natural enemies, (ii) use these models in conjunction with multi-objective algorithms in order to design landscape pattern for pests control, (iii) include agro-economical information to the models in order to, finally, (iv) build the eco-efficiency production frontier of the landscape patterns (task 6).
The recruited person should have a PhD in applied mathematics and skills in modeling and/or non linear multi-objective optimization. He will be supervised by Mohamed-Mahmoud Ould-Sidi (optimization, PSH) and Nicolas Parisey (modeling, IGEPP) with frequent interactions with Vincent Martinet (EP, Grignon) for the integration of economical information.

8.6.2 PARTNER IGEPP

***PhD thesis, year 1-3, tasks 1 to 3, Angers, ANR funding 50%* (18 months)**

The influence of non-crop vegetation on predators of pest insects is quite well documented (Frei & Manhart, Landis et al 2002, Bianchi et al 2006, Geneau et al 2012). Usually positive effects on these beneficial insects have been reported which has resulted in several approaches to sow plant species in field margins in order to improve pest control (Haaland et al 2012). However, the effect on pest insects and crop damage has rarely been studied (Pfiffner et al 2003). Due to the complex foodweb structure linking the different trophic levels, a vegetation mediated increase in pest predators does not always result in a significant reduction of pest insect populations. Species of the non-crop vegetation may also attract pest insects and increase crop infestation (Franck 1998, Le Guigo et al in press) and vegetation effect may depend on landscape structure and land use intensity.

The first objective of the thesis is to evaluate relationships between field margin vegetation and crop pest control using a correlative analysis at different fields in different landscapes. Vegetation surveys will include species diversity, plant cover and phenology. The analyses will focus on wheat/oil seed rape rotations, the dominant crop herbivores in this system (aphids and pollen beetles) and the main predators (parasitic wasps, hoverflies). Aim of this correlative study is the identification of plant species, functional groups and diversity parameters that have a suppressive effect on pest insects in an agroecosystem context. The effect of species composition and diversity of plant communities will be compared with the influence of landscape attributes such as density of hedgerows or area of semi-natural habitats. The analysis allows a comparison of the magnitude of landscape and vegetation effects and the test their interactions.

The second objective is a more detailed identification of plant species that are resources for hoverflies and parasitic wasps as predators (parasitoids) of the most important pest insects in wheat and oilseed rape. Both groups are carnivore pest predators (parasitoids) during their larval stages but nectarivore as adults. An analysis of the gut content (pollen) allows an identification of the preferred plant species. Observations on flowering plants (flower visitors) will help to evaluate their attractiveness for beneficial insects. The spontaneous field margin vegetation may also provide resources for non-pest herbivores that represent alternative prey (or hosts) for beneficial insects. The presence of this alternative prey/host will be analysed on different plant species.

The third objective is to test the plant species identified in the correlative and the functional analyses in wildflower strips sown into the field margins. Mixtures of theses candidate plants will be tested against grass strips and spontaneous vegetation as a control. Their efficiency in suppressing pest insects will be analysed in all species tested in the correlative study. In a second approach, the efficiency of plant functional traits will be tested against species identity in order to evaluate whether candidate plants can be replaced by other species of the same functional group.

Postdoc, year 1, tasks 4, Rennes, ANR funding (12 months)

Ecosystem service of biocontrol depends on the structure of the foodweb surrounding the pests and its functioning. Consequently, the efficiency of management options on pest control services results from the changes in the foodweb functioning they induce. The post-

doc will have to use high throughput sequencing to analyse the gut content of the main species of natural enemies of pests found in the field. Those data, combined with data obtained from population dynamics analyses and from stable isotopes ratio and pollen identifications will be used to build the trophic networks surrounding pest species in the field. The properties of those networks will be studied in relation with the local (floral strips, agricultural practices,...) and landscape factors. Connexion between field networks and margin networks and the factors enhancing them will be especially studied. Results will be used to draw prediction on the quality of ecosystem service of bioncotrol according to local ecological management and surrounding landscape.
Ideally, the applicant should have carried out his (her) PhD on community ecology and especially on trophic ecology and should possess a good knowledge on next generation sequencing.

8.6.3 PARTNER AGRONOMIE

PhD thesis, year 1-3, tasks 4 and 5, Grignon, ANR funding 50% (18 months)
Non-crop habitats and cultural practices sometimes have antagonistic effects on crop pests and natural pest control, e.g. when ecological engineering aimed at enhancing pest control also increases pest multiplication. Solving this problem, i.e. optimising the landscape to reach objectives such as crop yield under reduced pesticide inputs, could be done if the different species reacted to landscape differently and/or at different spatial scales: using spatially explicit models, it could then be possible to design landscape configurations favourable to natural enemies and not too favourable to pests. This approach has been undertaken to design landscapes optimising the natural control of pollen beetle, an important pest attacking oilseed rape and controlled by a parasitoid. To this aim, a model has been developed and parameterized based on data present in the literature (Vinatier et al, 2012a). However, a sensitivity analysis has showed that the model outputs are very dependent upon the values of the parameters describing the pest's and parasitoid's dispersals (Vinatier et al, 2012b). Furthermore, no precise estimates of these dispersal parameters are available in the literature, because long distance dispersal is particularly difficult to study experimentally. New methods based on molecular markers, such as kinship analyses, can be used to obtain better estimates of individual movement (Franck et al 2011). The first step in the PhD will be to develop molecular markers that are adapted to this method for pollen beetle and its parasitoid. The second step will be to use them on individuals collected in tasks 1 and 2 to understand the pest's and parasitoid's dispersals and their relationships with environmental factors. This approach may be combined with classic mark-release-recapture experiments to assess the movement of the insects among and between semi-natural habitat patches and crop fields. The third step will be to integrate this knowledge as parameters of the spatially explicit model to design landscapes conducive to the parasitoid and suppressive against the pest. The applicant should have a Master's degree in ecology or agronomy, with skills in molecular biology and an interest in modeling. The PhD will be co-tutored by Grignon and Avignon.

8.6.4 PARTNER BIOSP

Postdoc, years 2-3, tasks 4.3, Avignon, ANR funding (12 months)

A 12-months post-doc will be hired to work on Task 4.3 in collaboration with Partner 5 and Partner 1 (mostly P Franck). Ideally, the postdoc would work for the project partially on years 2 and 3, when the codling moth dataset will be complete. Collaboration with Partner 2 in Rennes will be encouraged.

Focusing mainly on the spatio-temporal dynamics of codling moths and parasitoids in an apple-orchards landscape, the candidate will have to model spatially explicit metapopulations where migration rates depend on distance, field and population sizes and landscape features. Including spatially explicit demography and genetic relatedness among individuals in the model will enable to use numerical statistics methods (e.g. Bayesian MCMC or ABC) to estimate important demographic and dispersal parameters (long-distance dispersal, population growth, Allee effects, and potentially their variations linked with landscape features).

The skills we expect from the candidate are (i) knowledge of principal mathematical models for spatio-temporal dynamics in population ecology, (ii) knowledge of the principal statistical methods in molecular ecology, (iii) knowledge of the principal methods used in numerical statistics. The candidate should be able to develop computer programs in R and/or C to implement the statistical methods developed in Task 4.3. Interests for agro-ecology, landscape ecology or epidemiology will be welcome but not compulsory.