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A methodology to compare specialized and mixed farming systems.

Case studies, in the Netherlands and France.

Master thesis

4th Cohort (2010-2012)

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Abstract

This master thesis was carried out at Plant Research International in Wageningen, the Netherlands, within the framework of the double degree in Agroecology between ISARA-Lyon in France and UMB in Norway. The study was part of the CANTOGETHER project. Standing for Crops and ANimals TOGETHER, this European project aims at promoting innovative mixed farming systems in several case studies of Europe. In this thesis, the aim was to create a methodology, composed of a set of economic, social and environmental indicators, in order to compare mixed and specialized farming system and to test the methodology in two case studies in the Netherlands and in France. The analysis relies on two farm typologies based on the concepts of representative and typical farms. Accordingly, the two-scale methodology uses the farm accountancy data network (FADN) to compare farming systems over large areas and agri-environmental data collected on-farm to design innovative farming systems. The results are a first step towards understanding up scaling procedure of innovative mixed farming systems at district level. While the municipality of Winterswijk shows a higher potential to develop between-farm mixing, the Ribéracois however presents better possibilities to develop diversified on-farm mixing. Very heterogeneous areas of Europe render difficult to set up a harmonized methodology. The data heterogeneity of case studies and the importance to make good use of existing information and specificities of each case study prevails on harmonizing the set of indicators. The scientific soundness and efficacy of the methodology is empirically verified but further study is needed to validate all indicators. Additionally, a selection of a primary set of information that is required by all work packages and all case studies is necessary to have a common basis for work.

• Mixed farming systems • Specialized farming systems • Methodology • Indicators • Farm Accountancy Data Network • Agri-environmental data • CANTOGETHER

TABLE OF CONTENT

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

AEM – Agri Environmental Measure

CANTOGETHER – Crops and ANimals Together

CAP - Common Agricultural Policy

CBS - Central bureau for statistics

COP – Cereals and Oil and Protein crops

CS - Case Study

DIALECTE - DIAgnosis Linking Environment and CTE

EU - European Union

FADN - Farm Accountancy Data Network\

FT - Farm Type

FWU - Family Working Unite

IDERICA - Indicateurs de Durabilité des Exploitations agricoles and Réseau d'Information Comptable Agricole

LEI - Agricultural Economics Research Institute

LU - Livestock Unite

MFS - Mixed Farming Systems

PRI - Plant Research International

UAA - Utilized Agricultural Area.

EXTENDED SUMMARY IN FRENCH

Introduction

Dans le cadre du double-diplôme Agroécologie[1] en partenariat entre l'UMB, l'université des sciences de la vie en Norvège et l'ISARA-Lyon, le mémoire de fin d'étude (MFE) est un challenge important du cursus. J'ai mené à bien mes recherches dans le centre de recherche « Plant Research International », à l'université de Wageningen aux Pays-Bas de janvier à juillet 2012 Mes recherches se sont inscrites au sein du projet CANTOGETHER (animaux et cultures ensemble).

Le projet CANTOGETHER vise à promouvoir les systèmes agricoles en polyculture élevage[2] (PE) innovants dans plusieurs études de cas en Europe. Le but de diminuer les impacts environnementaux des exploitations européennes, optimiser l'utilisation de l'énergie et des nutriments, conserver les ressources naturelles, diminuer les gaz à effet de serre tout en maintenant le niveau de production (CANTOGETHER, 2011). Les innovations prévues par CANTOGETHER porteront sur les transports de matière (effluents d'élevage, céréales, fourrages, pailles etc.), des pratiques de fertilisation raisonnées, la diminution de l'utilisation d'énergies non-renouvelables et la promotion d'énergies renouvelables. Ainsi, ces innovations ont pour but d'améliorer le cycle des nutriments à l'échelle des exploitations ou des régions agricoles, d'augmenter l'autosuffisance des exploitations, de régénérer la matière organique des sols et de diminuer les exports de fumiers et de lisier sur de trop longues distances.

Pour ce faire, vingt-quatre régions pilotes ont été sélectionnées pour mettre en place différentes innovations. Le projet comprend sept groupes de travail[3] composés de plusieurs tâches. Mon MFE s'inscrit dans la tache 3.1 dont le but est d'étudier les différents systèmes agricoles et leurs interactions à l'échelle du territoire et de définir une méthodologie pour collecter les données nécessaires à

[1] L'Agroécologie se définit comme une science, une pratique et un mouvement et comprend des sciences sociales, de l'agronomie, de l'écologie etc. Cela concerne l'étude des systèmes agricoles et agroalimentaires à tous les niveaux avec leurs multiples interactions. Cette discipline émergente est adaptée aux problèmes complexes du système agro-alimentaire. Dans le but de mieux comprendre et innover dans ces systèmes, l'Agroécologie étudie la durabilité des agroécosystèmes dans leur contexte socioéconomique (Altieri, 1989). La pensée systémique est un outil important afin de mieux comprendre ces systèmes et lier les idées et théories avec l'observation et la pratique.

[2] CANTOGETHER considère les exploitations en PE de deux manières : i) une exploitation comprenant les productions animales et végétales au sein de la même unité de gestion ; ii) et des exploitations spécialisées en productions animales et végétales mettant en œuvre des échanges de matières (céréales, pailles, fumier etc.).
[2] WP1 définit les innovations qu'il serait envisageable de mettre en place dans chaque étude de cas. WP2 et WP3 analyse respectivement les implications de ces innovations à l'échelle de l'exploitation puis du territoire. WP4 et WP réalisent respectivement une analyse environnementale et économique des innovations. WP6 assure la communication et dissémination d'information et WP7 administre le management global du projet.

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l'évaluation et la mise en place d'innovations. Une multitude d'acteurs sont impliqués tels que des centres de recherche, des entreprises, des exploitants agricole, des associations environnementalistes etc. Cependant, ce projet se concentre sur la mise en place technique d'améliorations environnementales et n'inclut aucune étude de marché.

Au sein du projet CANTOGETHER, l'objectif de mon MFE est de créer une méthodologie afin de comparer la durabilité des exploitations en polyculture élevage d'une part, et des exploitations spécialisées d'autre part. Cette étude est une première étape vers l'analyse des impacts territoriaux de pratiques innovantes dans différentes exploitations. Les systèmes agricoles étudiés comprennent plus particulièrement des exploitations céréalières et des exploitations laitières. Cette méthodologie, basée sur une sélection d'indicateurs économique, environnemental et social, est testée dans deux études de cas, en France et aux Pays-Bas. Les résultats de cette étude permettent de déterminer quelles sont les innovations qui semblent être les plus appropriées dans chaque région.

La première partie de cette étude replace le projet dans le contexte de l'agriculture en Europe et introduit la notion d'agriculture durable avant de détailler les problématiques spécifiques à l'agriculture de nos jours sur lesquels s'appuis ma problématique. L'étude se déroule en plusieurs étapes : i) l'identification d'objectifs majeurs du projet CANTOGETHER : ii) l'identification de critères et indicateurs répondant aux objectifs principaux ; iii) la détermination de fermes typiques dans deux études de cas, en France et aux Pays-Bas ; iv) l'analyse et la comparaison d'exploitations spécialisés et en polyculture élevage ; v) et l'évaluation de la qualité des indicateurs et de l'efficacité de la méthodologie pour supporter la mise en place d'innovations dans différents études de cas. La rigueur scientifique et l'utilité de cette méthodologie sont discutées et quelques pistes d'amélioration sont présentées.

1. L'agriculture en Europe : de l'histoire aux problèmes actuels

L'agriculture en Europe a été profondément transformée durant les dernières décennies. Dans la première moitié du 20ème siècle l'agriculture était caractérisée pas un grand nombre de fermes en PE ainsi qu'un nombre important d'agriculteurs. Les fermes familiales à vocation d'autosuffisance alimentaire dominaient alors le paysage rural en Europe (Oomen et al., 1998). Après la seconde guerre mondiale, la Politique Agricole Commune (PAC) a été créée dans le but de produire suffisamment pour subvenir aux besoins alimentaires de la population afin de chasser la faim, alors très présente en Europe. La priorité était de développer des systèmes agricole productifs caractérisés par un degré élevé de spécialisation, peu, voire pas de rotation de cultures et une utilisation massive d'intrants tel que des pesticides, des fertiliseurs ou des concentrés pour nourrir le bétail (Oomen et al., 1998).

De nos jours, les agriculteurs conventionnels utilisent d'importantes quantités d'intrants pour réaliser une importante quantité de produit, tout en diminuant les coûts de main d'œuvre par hectare et augmentant les déchets produits (Van Keulen et Schiere, 2004 et Meerburg et al., 2009). Le développement de la mécanisation a permis aux agriculteurs de faire des économies d'échelle et d'accéder à de nouveaux marchés. Le paysage rural à travers toute l'Europe a été largement façonné par l'industrialisation et la spécialisation, principaux vecteurs des importantes problématiques agricoles que nous connaissons aujourd'hui. Le début du 21eme siècle affiche une campagne uniforme avec de multiples difficultés. Intensification, homogénéisation du paysage, fragmentation des habitats naturels et érosion de la biodiversité (Meerburg et al., 2009) incitent l'agriculture à redéfinir sa relation avec la nature.

En outre, les principaux enjeux de l'agriculture d'aujourd'hui comprennent une demande croissante pour les produits d'origine animale, accentuée par la croissance de la population et les changements de régimes alimentaires. La pression exercée sur la biomasse pour la nourriture du bétail augmente avec la compétition croissante de cette biomasse pour la nourriture humaine, animale, pour les fertiliseurs et les agro-carburants (Herrero et al., 2010). La croissance de la population stimule la compétition pour les ressources naturelles telles que le sol ou l'eau avec d'autres secteurs tels que l'urbanisation, le développement d'infrastructures ou l'implantation d'industries (OCDE, 2010). Aussi, la production agricole, profondément ancrée dans la tradition et guidée par la recherche de profit, est intimement liée aux problématiques du changement climatique concernant les émissions de gaz à effet de serre, la pollution et la raréfaction des ressources naturelles causée par notre impact préjudiciable sur les écosystèmes (Eurostat, 2011).

Il y a un besoin évident de créer des systèmes de production socialement, économiquement et environnementalement acceptables pour les citoyens, les agriculteurs et la nature (Meerburg et al., 2009). Dans le prolongement de ce constat, les productions animales devraient être liées à l'environnent et perçues à travers les aspects humains, économiques et politiques mais également à travers l'utilisation des ressources naturelles (Steinfeld et al., 1995). Ainsi, un équilibre entre l'intensité des productions animales et végétales doit être atteint à une échelle locale, régionale et nationale (CANTOGETHER, 2011) dans le but de satisfaire nos besoins imminents de production. De plus, les modes de consommation et de production de demain devraient être durables afin de maintenir notre écosystème global et de répondre aux attentes actuelles de la société concernant le développement de systèmes durables. Ainsi, il faut continuer à satisfaire les besoins basiques des citoyens Européens tout en améliorant les conditions de vie et minimisant la consommation de ressources naturelles (Eurostat, 2011). L'agriculture se doit de ne pas compromettre la possibilité pour les générations futures d'assurer leurs besoins (De Schutter, 2010). Un des buts de la PAC post 2013 est de rendre les politiques plus justes, plus vertes, plus efficaces et adaptées, compréhensibles et offrant plus de services aux citoyens Européens que la « simple » sécurité alimentaire (EC, 2011).

A l'aube du 21ème siècle, la relation entre les hommes et la nature devient de plus en plus importante et a une influence marquée sur le développement des sociétés, et en particulier la façon dont sont conçus les agroécosystèmes. Il en va du futur de l'humanité de réorienter nos manières de produire vers des systèmes plus justes socialement et responsables du point de vue environnemental (De Schutter, 2010). Les cycles des nutriments ainsi que la diversité biologiques sont des leviers d'action fondamentaux pour repenser nos systèmes de production (Edwards et al., 1993; Lang et al., 2012). Cependant, ces systèmes naturels font partie intégrante de nos systèmes sociaux et leurs multiples implications les rendent difficile à étudier. Par exemple, le fait que certains agriculteurs considèrent les effluents d'élevage comme des déchets et non pas comme une ressource, en raison de la séparation spatiale des zones d'élevage et des zones céréalières, ainsi qu'à l'accessibilité et praticité des fertiliseurs minéraux (Van der Meer, 2008), sont des obstacles supplémentaires au développement durable.

Les exploitations en PE intégrant des productions végétales mais aussi animales sont très adaptées au maintien de la fertilité des sols et réduisent la dépendance des exploitations aux énergies fossiles (De Schutter, 2010). Ces systèmes en PE ont une forte dépendance au contexte pédoclimatique et socio-économique et il est particulièrement important de promouvoir des pratiques et politiques adaptées à la situation locale. Le développement de modèle pour mesurer les balances énergétiques et de nutriments est primordial afin de mettre en place des stratégies adaptées et développer des références en Europe (De Haan et al., 1996).

A la lumière de ces constats, ma problématique se définit comme suit : mettre en place une méthodologie basée sur des indicateurs sociaux, environnementaux et économiques à l'échelle de l'exploitation afin de comparer la durabilité des systèmes en PE avec des exploitations spécialisées. Cette méthodologie devrait être une première étape pour interpréter les impacts des exploitations à l'échelle du territoire dans le but d'évaluer le potentiel pour développer des fermes en PE innovantes dans deux études de cas.

En de basant sur ces objectifs, l'hypothèse suivante est mis à l'épreuve : il est possible de comparer des exploitations spécialisées et en PE avec une sélection unique d'indicateurs dans plusieurs études de cas en Europe afin d'étudier le potentiel pour mettre en place des systèmes agraires innovants.

2. Matériels et Méthodes

La méthodologie repose sur deux concepts principaux. D'une part celui de fermes typiques dont le but est de capturer le potentiel pour mettre en place des innovations. Ces fermes sont typiques de la région et rendent compte des contraintes physiques des agriculteurs grâce à une sélection soigneuse par des experts des variables pertinentes pour décrire les exploitations. Et d'autre part le concept de fermes représentatives, qui est un concept statistique où les exploitations sont le résultat de moyennes de groupes d'exploitations. Ce concept est utilisé pour étudier l'influence des politiques sur différents groupes d'agriculteurs à de grandes échelles. Ces deux concepts utilisent des données différentes pour construire le profil des exploitations. Alors que les fermes typiques utilisent des données locales collectées sur le terrain et sont exprimées à l'aide d'indicateurs agri-environnementaux, les fermes représentatives proviennent de la base de données européenne RICA[4].

Cette analyse à deux niveaux se fait à l'aide d'indicateurs. Ceux-ci sont groupés en deux classes : les indicateurs simples faisant usage de mesures ou d'estimations (comme les indicateurs locaux) et des indicateurs complexes regroupant plusieurs indicateurs simples en indicateurs composites (comme c'est le cas pour les données RICA). En général, les indicateurs RICA traitent des données économiques et les indicateurs agri-environnementaux traitent des informations agronomique. Ces derniers indicateurs sont très spécifiques et renseignent précisément sur la situation locale mais sont laborieux à collecter et leur usage sera contraint par les ressources du projet CANTOGETHER (temps et argent étant limités). Dans les deux cas, tous les indicateurs sont empruntés aux méthodes IDERICA (Girardin et al., 2004), adaptée aux données du RICA et IDEA (Solagro, 2011), adaptée aux données locales.

Comme la méthodologie pour valider des indicateurs environnementaux développée par Bockstaller et Girardin (2003) le suggère, chaque indicateur répond à un but précis. Ainsi, les objectifs principaux du projet CANTOGETHER seront la base du développement de cette méthodologie. Dans un second temps, les objectifs sont déclinés en sous-objectifs plus précis. Ensuite, à chaque sous-objectif est

[4] RICA (Réseau d'Information Comptable Agricole), est une base de données économique d'exploitations agricoles en Europe et ne regroupe que les moyennes et grandes exploitations (marge brute potentielle supérieure à 25000€). Les exploitations sont classifiées à l'aide du volume économique dégagé par chaque type de production.

associé un critère qui est une manière d'exprimer cet objectif. Finalement, des indicateurs permettront de quantifier chaque critère. Afin de déterminer les indicateurs appropriés pour chaque critère, il faut non seulement considérer les objectifs à atteindre mais également les données déjà disponibles dans les études de cas afin de permettre une analyse rapide et peu coûteuse.

Afin de sélectionner un set d'indicateur approprié, plusieurs paramètres ont influencés mes choix. Tout d'abord, il est important d'avoir des indicateurs qui représentent les 4 objectives principaux du projet CANTOGETHER que sont i)de réduire la dépendance en intrants ; ii)d'assurer une bonne efficacité d'utilisation des ressources ; iii)d'avoir des performances environnementales acceptables et ; iv)d'avoir des performances économique acceptable. Le deuxième critère important est de sélectionner des indicateurs sociaux, économiques et environnementaux qui satisfont les trois piliers du développement durable. Le troisième critère est de sélectionner avant tout des indicateurs communément utilisés qui sont fiables venant des méthodes IDERICA et DIALECT. Finalement, il est primordial d'avoir des indicateurs aux 2 échelles étudiées, RICA et locale.

Pour que la méthodologie repose sur des indicateurs il est essentiel de définir quel seront les utilisateurs de cette méthodologie ainsi que les échelles de temps et d'espace. L'ensemble d'indicateurs sélectionné est utile en premier lieu pour les chercheur investis dans le projet CANTOGETHER. Les agriculteurs bénéficieront dans un second temps des innovations apportées. Concernant l'échelle de temps, les indicateurs utilisent des données pour une année, 2009 pour les donnes RICA et 2010 pour les bases de données nationales. Parfois, les données de 2008 et 2007 sont également utilisées pour montrer une évolution des valeurs prises par certains indicateurs. L'unité spatiale utilisée est l'exploitation agricole ce qui permet une collecte plus aisée des informations.

Finalement, la méthodologie est testée dans deux études de cas. La première est située à l'est des Pays-Bas dans la commune de Winterswijk et la seconde dans le sud-ouest de la France, dans la petite région agricole du Ribéracois.

Dans la base de données RICA, les Pays-Bas sont une seul région bien qu'ils comportent d'importantes hétérogénéités pédoclimatique et socio-économiques. Cependant, 72% des exploitations sont au-dessus du seuil des 25000€ de marge brute et exploitent 93% de la SAU (Surface Agricole Utile). Winterswijk est une petite commune à l'est du pays et présente une paysage agricole particulier avec de nombreuses haies et de petites parcelles. 64% des surfaces sont en prairies, 23% cultivées avec des fourrages et seulement 11% sont cultivées de cultures arables notamment des pommes de terre et des betteraves fourragères. La commune comprend 157 exploitations laitières, 95 exploitations allaitantes et 57 céréaliers. Globalement, les habitants et les agriculteurs sont soucieux de l'environnement et de nombreux projets ont été mis en place pour diminuer les pollutions agricoles. Les fermes étudiées dans cette étude de cas sont des élevages laitiers spécialisés, des exploitations arables et en PE ayant pour activité principale la production de lait.

La région RICA concerne l'Aquitaine, qui présente également d'importantes hétérogénéités. En Dordogne, seulement 48% des exploitations sur 85% de la SAU sont au-dessus du seuil économique des 25000€ de marge brute. Les fermes en polyculture élevages sont sur le déclin ces dix dernières années et ont diminué de moitié (Agreste, 2010b). Le Ribéracois comprend 70 communes situées au nord de la Dordogne avec une topographie accidentée, et des parcelles plus ou moins grandes. Les productions ovine, céréalière et allaitante sont les productions majeures. L'étude de cas se base sur un ensemble d'exploitations en agriculture biologique dispersées à travers le Ribéracois et comprenant toutes sortes de fermes. Dans cette étude, les fermes analysées sont des fermes en PE ovins laitiers, des fermes arables et des exploitations laitières.

Les deux études de cas sont très différentes de tous points de vue ce qui permet de faire face au défi de développer une méthodologie harmonisée à travers l'Europe. Il est ainsi possible de tester la capacité de la méthodologie à s'adapter à différents contextes socio-économiques et pédoclimatiques. Cette hétérogénéité des études de cas nécessite donc que la méthodologie soit suffisamment flexible.

3. Résultats

- Winterswijk

Aux Pays-Bas, les exploitations spécialisées céréalières montrent des résultats beaucoup plus encourageants selon les indicateurs choisis que les exploitations laitières ou en PE. Aussi, les exploitations laitières montrent principalement des résultats en dessous de la moyenne et il semble qu'il y ait peu d'incitations à démarrer une exploitation pour les jeunes agriculteurs (il est important de prendre en considération les investissements importants réalisés en 2007 ce qui impacte fortement les revenus en 2009). Néanmoins, ces exploitations montrent des résultats supérieurs à la moyenne quant aux aides agri-environnementales par hectare grâce aux importantes surfaces en prairies permanentes. Ceci est dû à l'importance des programmes de protection des oiseaux qui ont besoin de prairies permanentes pour faire leur nid et se reproduire. L'efficacité de production est la moins bonne pour les exploitations en PE à cause de leur faible moyenne sur les trois années mesurées (07, 08, 09).

Cependant, celle des exploitations laitières est largement négative en 2009 à cause des forts investissements réalisés les années précédentes contrairement aux exploitations en PE qui ont des résultats beaucoup plus stables dans le temps. Cette stabilité est un avantage important et permet aux agriculteurs de mieux gérer leurs investissements. Globalement, les exploitations en PE présentent des résultats moyens et ne montrent pas d'avantages marqués. Malgré tout, ces systèmes restent intéressants à considérer.

Localement, les exploitations laitières ont tendance à produire de meilleurs résultats que les exploitations céréalières spécialisées et en PE. Cette tendance est accentuée par le fait que ces systèmes utilisent leurs propres effluents d'élevage pour la fertilisation. Bien que les taux d'application soient augmentés à 250 kg N/ha aux Pays-Bas sous certaines conditions[5], ces exploitations exportent une partie de leurs lisiers. Cela représente une contrainte économique pour les agriculteurs mais également une contrainte environnementale pour la région. De la même façon, les exploitations céréalières accroissent la pression environnementale en important la totalité de leurs fertiliseurs sous forme minérale, ces derniers reposant sur des procédés pétrochimiques et de longe distances de transport. Ainsi, les échanges entre fermes spécialisées arable et spécialisées laitière apporteraient des bénéfices certains aux deux types d'exploitations du point de vue de leur profil environnemental. Finalement, les exploitations en PE ne couvrent pas la totalité de leurs besoins en fertilisation avec leur propres effluents d'élevage et il peut s'avérer intéressant pour ces exploitations d'ajuster le nombre d'animaux aux surfaces cultivées (une légère augmentation des troupeaux serait à envisager).

Aux Pays-Bas, la spécialisation des exploitations a été un phénomène marqué et il semble inacceptable de revenir sur des systèmes en PE. Les exploitations en PE présentes sont principalement deux productions spécialisées au sein d'une même unité de gestion. Néanmoins, les sommes importantes d'argent dépensées par les agriculteurs pour exporter les surplus de lisiers pourraient être une motivation importante pour mettre en place des coopérations régionales et des systèmes de fermes mixtes à l'échelle territoriale. Cependant, ces échanges ne peuvent fonctionner seulement si ceux-ci sont intéressants économiquement pour les agriculteurs et si les habitants de la commune acceptent des nouvelles pratiques. Aussi, un certain nombre de barrières peuvent survenir telles que la capacité des routes à faire passer des camions ou encore les mauvaises odeurs durant les périodes d'épandage etc.

- Le Ribéracois

En Aquitaine, les exploitations en PE présentent des résultats plutôt positifs en comparaison aux exploitations céréalières et aux élevages ovins et caprins. Elles ont plusieurs points positifs tels que

[5] Aux Pays-Bas, lorsqu'une exploitation a au moins 70% de sa surface agricole en herbe, il est possible d'appliquer jusqu'à 250 kg d'azote par hectare de pré et de culture fourragère.

l'importance des flux de matière au sein de la ferme ou leur capacité à honorer leurs dettes et d'investir par rapport à leur capacité de production. Aussi, la rémunération du travail dans ces exploitations est meilleure que dans les exploitations laitières ce qui est un facteur important pour ces systèmes. A l'opposé, les exploitations spécialisées céréales montrent des performances homogènes mais relativement basses pour presque tous les critères. En général, l'agriculture en Aquitaine est très dépendante des subventions (jusqu'à 80% des revenus des exploitations céréalières, ovines et caprines) comparé aux Pays-Bas (en moyenne 15% des revenus). Cet aspect donne aussi raison aux systèmes en PE dont les revenus dépendent « seulement » à 60% des aides gouvernementales.

Dans le Ribéracois, les fermes en PE ont des caractéristiques intéressantes pour tous les paramètres pris en compte excepté pour les faibles surfaces en prairies permanentes. La diversité des cultures est mise en avant par rapport à la biodiversité. Finalement, les exploitations spécialisées arable ont un profil peu intéressant et ne présentent qu'un point fort, une nutrition azote et phosphore équilibrée. L'agriculture biologique est particulière et n'utilise que des engrais organiques, promeut la matière organique des sols et de faibles chargements animaux sont obligatoires ce qui favorise l'autosuffisance en fourrages et la bonne utilisation des ressources naturelles présentes sur l'exploitation. De plus, les politiques locales encouragent fortement la diversification et la distribution en circuits courts (Agreste, 2010b). Malgré tout, le développement de l'agriculture biologique reste très marqué par la disponibilité des produits en amont de la production et la possibilité de livrer les productions à des distances raisonnables du siège de l'exploitation.

Le Ribéracois présente peu d'opportunités pour le développement de fermes mixtes à l'échelle du territoire si l'on considère seulement les exploitations en agriculture biologique puisque ces exploitations considèrent les effluents d'élevage comme une ressource et non comme un déchet. Aussi, leur structure est adaptée à l'utilisation totale des effluents d'élevage. La seule possibilité de développer des exploitations mixtes à l'échelle du territoire serait de prendre en considération les échanges de matières avec des exploitations conventionnelles. Cependant, le territoire étant vaste et les exploitations dispersées, la mise en place de tels échanges pourrait être compliquée et coûteuse. De plus, la promotion d'exploitations en PE est rendue difficile à cause des contraintes que l'élevage représente. Les jeunes agriculteurs ne veulent plus accepter de telles contraintes excepté pour quelques rares cas où l'exploitant est convaincu ou passionné (Emanuel Marseille[6] en interview, 2012)

[6] Emanuel Marseille est le directeur de "AgroBio Perigord", une association locale pour le développement et la promotion de l'agriculture biologique.

4. Discussion

- Plusieurs typologies d'exploitation

La méthodologie repose sur les deux principaux concepts de ferme représentative et de ferme typique. Cependant, ces deux concepts utilisent des données et des typologies différentes. Alors que les fermes représentatives utilisent la typologie de la base de données RICA qui repose sur une classification économique des exploitations, les fermes typiques utilisent des données locales et une définition plus « environnementale » des fermes mixtes selon les objectifs du projet CANTOGETHER. Extrapoler les résultats pour quelques fermes a un ensemble de fermes de la région impose de décrire précisément ces fermes typiques. Selon Vayssières et al. (2011) très peu de projets se basant sur le développement de fermes typique et la validation scientifique de leur construction posent problèmes lors de l'extrapolation des résultats à l'échelle territoriale. Utiliser correctement le concept de ferme typique est complexe (Kölrich et al., 2003) et pour satisfaire les exigences scientifiques d'une typification il est nécessaire de s'accorder sur une méthode commune pour construire ces exploitations.

Le fait que la méthodologie se base sur deux échelles étudiées en parallèle, avec un manque critique d'articulation, empêche une analyse homogène des territoires. Une étude approfondie de ce sujet a été menée à bien par le projet SEAMLESS (Janssen et al., 2009) et ne présente pas de résultats satisfaisants en raison des investissements trop importants ainsi que du manque de temps et d'implication des pays membres de l'Union Européenne. Bien que le but du projet CANTOGETHER n'est pas d'articuler les typologies d'exploitation entre elles, cette méthodologie bénéficierait grandement d'être mise à l'épreuve dans d'autres études de cas. C'est la raison pour laquelle il a été décidé[7] de ne pas construire de ferme typique mais de baser l'extrapolation à l'échelle de territoire sur des cas réels d'exploitations participantes. Finalement, l'analyse RICA sera indépendante et ne concernera qu'une analyse économique. Il est intéressant de considérer l'article d'Andersen et al. (2007) qui développe une extension environnementale de la typologie adoptée par RICA afin de permettre des recommandations pour les politiques environnementale de la Politique Agricole Commune (PAC).

- Les indicateurs

Puisque la méthodologie repose sur la sélection d'un set d'indicateurs, leur spécificité et précision influence grandement la fiabilité de la méthodologie. Celle-ci varie selon les indicateurs choisis à chaque niveau d'analyse mais aussi selon leur nombre. Ces informations sont subjectives et dépendent principalement du temps et du budget disponible pour le projet. Cela dépend des études de cas sélectionnées pour une analyse approfondie et celles pour une analyse superficielle. Aussi, chaque

[7] Lors de la réunion du 26 et 27 Juin 2012 organisée a Wageningen avec tous les participants du groupe de travail numéro 3.

étude de cas se verra appliquer un set d'indicateur commun, résumant les informations principales et un set spécifique tenant compte des particularités de cette région. Ce second cas ne concerne que les études de cas approfondies. En conséquence, plus le panel d'indicateurs disponible est large plus la sélection peut être appropriée dans chaque région.

De plus, la sélection d'une valeur de référence est indispensable afin de juger la qualité de la réponse donnée par les indicateurs (Halberg et al., 2005). Seulement les indicateur appliqués à la base de données RICA ont une valeur de référence et les indicateurs agri-environnementaux sont jugés par les experts dans chaque étude de cas. Dans ce dernier cas, les acteurs peuvent définir leurs propres valeurs de références selon le concept de « Benchmarking[8] » ou étalonnage. Pour les indicateurs RICA, j'ai choisi comme valeur de référence des moyennes de groupe entre toutes les productions ou en excluant certaines productions quand leur résultats biaisent l'interprétation. Cependant, ces valeurs sont subjectives et il est également possible de sélectionner des quartiles ou la médiane par exemple. Il me semblait judicieux de considérer une moyenne puisque la base de données RICA n'utilise que des données moyennes.

- Le changement d'échelle

C'est précisément le but de la tache 3.1 de déterminer le potentiel pour développer des systèmes de fermes mixtes à l'échelle de la région. La procédure de changement d'échelle peut se baser sur la description de fermes typiques et est caractérisée par trois dimensions : l'espace, le temps et la complexité (De Vries et al., 1993 cites dans Bechini et al., 2001). La dimension spatiale renvoie à l'augmentation du nombre de fermes et la dimension du territoire. La dimension temporelle réfère à l'analyse du présent pour prévoir le future ou à l'analyse de plusieurs années pour rendre les interprétations plus robustes face aux imprévus. Finalement, la complexité renvoie à la perte de précision liée à l'agrégation de données. De plus, les indicateur agri-environnementaux sont très sensibles aux changements d'échelles et les erreurs de précision se répercutent rapidement (Bechini et al., 2001). Enfin, l'étude de régions agricoles impose de laisser une place de plus en plus importante aux décisions des acteurs impliqués et aux politiques locales mises en avant (Halberg et al., 2005). En ajoutant le fait que la description de fermes typique est laborieuse et complexe, le projet CANTOGETHER adoptera une démarche différente et toute innovation sera ponctuelle. Dans un second temps, probablement après l'échéance du projet, chaque région sera responsable pour une mise en œuvre plus généralisée de certaines innovations.

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[8] Etalonnage est le processus de faire progresser ses performances en identifiant, comprenant et adaptant continuellement ses pratiques a ses propres capacités et les potentialités de la région (EEA, 2001).

Conclusion

Finalement il est difficile de parler de diagnostic durabilité puisque la méthodologie utilise principalement des données économiques, quelques données environnementales et pratiquement aucune donnée sociale. Il a été mentionné lors de la conférence du 26-27 juin 2012 que des indicateurs sociaux d'acceptation des innovations par les habitants seront importants à prendre en compte pour permettre d'évaluer le succès de la mise en place de pratiques innovantes. Aussi, une liste d'indicateurs environnementaux plus complète offrirait une plus grande flexibilité à la méthodologie afin de mieux s'adapter à des régions et données disponibles différentes.

Les deux analyses, locale et RICA ne seront pas articulées entre elles. Cependant, selon les études de cas, l'une ou l'autre des analyses sera mise en valeur en fonction du temps et du budget disponible. Aussi, il parait plus important de faire un bon usage des données déjà existantes sur le terrain plutôt que de chercher une harmonisation de la méthodologie. C'est pourquoi, l'analyse RICA sera la seule à permettre une analyse économique harmonisée[9] à travers l'Europe. Les évaluations locales seront circonstanciées en fonction des particularités de chaque étude de cas. Cela implique que la méthodologie soit testée dans d'autres études de cas afin de mettre en relief d'éventuels manques et l'adapter de nouveau.

D'un point de vu pratique, les deux études de cas ont donnés des résultats contrastés. Tandis que Winterswijk présente de meilleures opportunités pour développer des coopérations régionales, le Ribéracois se montre plus approprié à la mise en place de fermes en PE. Dans le premier cas, les exploitations sont très spécialisées et les gens ne sont pas prêts à revenir sur des systèmes plus diversifiés. Cependant, des échanges entre exploitations pourront, sous réserve d'être acceptable du point de vu des agriculteurs et des habitants de la commune, se mettre en place rapidement. Dans le second cas, les distances importantes entre exploitations rend les échanges difficiles. De plus, les exploitations en agriculture biologique tendent à l'autonomie et à la diversification plus facilement que les exploitations en agriculture conventionnelle ce qui favorise la mise en place de fermes en PE.

Globalement, cette étude a été difficile à mettre en place car les objectifs du projet sont restés peu clairs durant les six premiers mois. A cette heure, beaucoup de choses ont été clarifiées. Bien que le projet CANTOGETHER soit ambitieux dans ses objectifs, sa structure complexe et le grand nombre d'acteurs qu'il implique, le temps et le budget restreints pourront s'avérer être des facteurs limitant quant à la bonne mise en place des innovations sur le terrain. D'autre part, le projet se concentre sur une perspective économique et environnementale mais sous-estime les données sociales. Finalement, les innovations ne sont pas insérés dans le contexte du marché dans lequel les agriculteurs évoluent ce

[9] Cette harmonisation est encore un challenge en Europe et des comparaisons entre pays doivent être effectuées avec grande précautions.

qui peut poser un problème de mise en place pratique pour certaines innovations. De plus, les performances techniques et environnementales des systèmes agricoles ne peuvent pas résoudre l'incapacité du marché à encourager les externalités positives des exploitations agricoles (IAASTD, 2008).

Pour terminer, du point de vue d'un agroécologue, ce MFE a été une réussite et j'ai eu l'opportunité de découvrir le monde de la recherche à travers un projet Européen et de comprendre les implications des politiques d'harmonisation en Europe. Les langues, cultures, climats, sols etc. sont extrêmement différents d'un pays à l'autre mais également au sein de chaque pays. A mon sens, les politiques uniques en Europe sont un non-sens et le secteur agricole a particulièrement besoin de politiques plus régionalisées à cause des fortes hétérogénéités présentes à tous les niveaux. Les bénéfices d'une Europe harmonisée sont discutables et particulièrement d'un point de vue environnemental et social. Cependant, les politiques actuelles se construisent principalement dans une perspective économique et il y a de fortes chances pour que cela perdure dans les années à venir.

Introduction

Within the frame of the double diploma program in Agroecology between ISARA-Lyon and UMB, I carried out my thesis at Plant Research International, in the Netherlands. Dr. Hein Korevaar, leader of the of the team "Multifunctional Land Use", offered me the chance to study in his research team under the "Agrosystems Research" business unit within the "Plant Science Group" of Wagenignen UR.

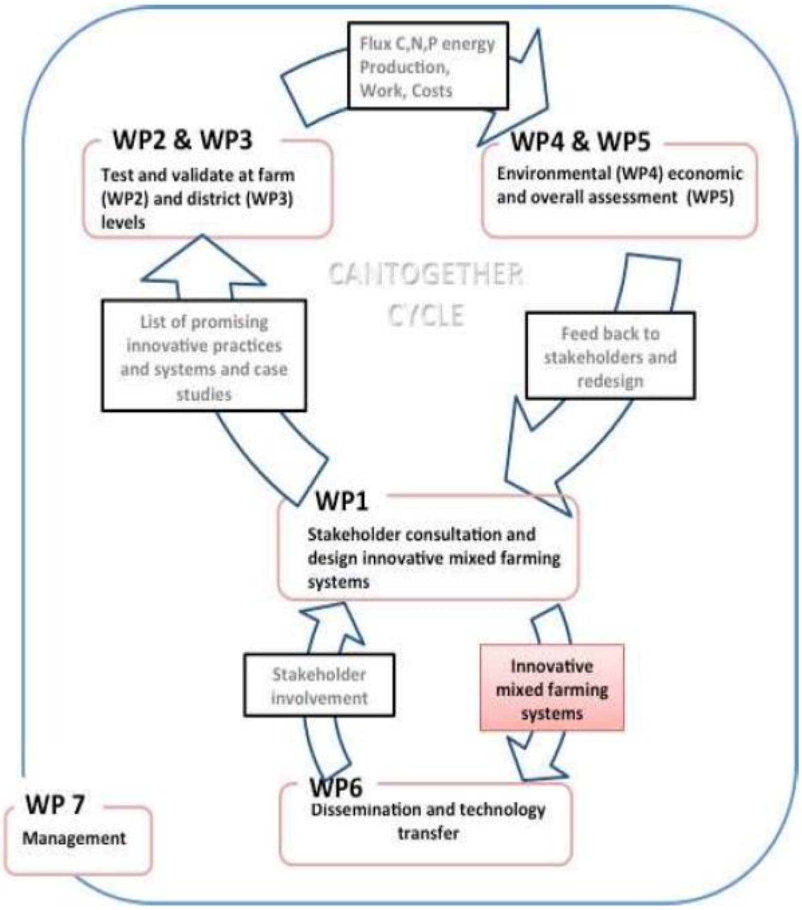
In recent years, our societies in Europe realize the implication of globalization for agriculture. The many issues that farmers, researchers, consumers or governments are facing currently are being addressed and all sort of projects are carried out throughout Europe. The concept of sustainability is chief and comes up recurrently in all kind of disciplines. It requires to comprehend issues through a more global approach, taking into account many disciplines and their relations to one another but also many stakeholders and their decisions. This reflection has guided me toward studying farming systems sustainability, and so did the CANTOGETHER project.

Standing for Crops and Animal TOGETHER, this European seven framework project, aimed at promoting innovative mixed farming systems, has much to offer in terms of multidisciplinary research. Involving 10 countries, researchers, small and medium enterprises and farmers work hand in hand to analyze, design and implement innovative farming practices and mixed farming systems. A wide range of other actors are involved such as extension services, policymakers, feed industry, nature conservation groups etc. (CANTOGETHER, 2011). The overarching goals of the project is to decrease environmental footprint of European farms and to decrease the emissions generated by transports, excess of fertilization and use of non-renewable energies. To do so, the project intends to develop sustainable mixed farming systems with the objective to close nutrient and energy cycles within farms and regions, increase the self-sufficiency of farms, decrease manure handling over long distances, preserve and make a better use of natural resources (water and soil), non-renewable resources (phosphorus and fossil fuels), as well as ecosystem services (pollination, natural pest control and soil fertility through soil organic matter content) (CANTOGETHER, 2011). CANTOGETHER strives to create systems that will ensure high resource-use efficiency, reduction in external inputs dependency and acceptable environmental and economic performances. These new mixed crop-livestock systems will be promoted at the farm and district level with innovative techniques and practices optimizing energy, nutrient and carbon flows. In turn it will enhance social, economic and environmental benefits of farms at both farm and district level.

So as to reach its goals, a network of 24 existing case studies throughout Europe will serve as a set of pilot regions for data collection and implementation of innovative farming practices (CANTOGETHER, 2011). Located in 5 biogeographical regions of Europe (Alpine, Nordic countries, Atlantic, Continental and Mediterranean), 8 experimental farms and 16 pilot areas will give physical relevance to the project. CANTOGETHER is structured in seven work packages, each of which bearing specific objectives. Figure 1 shows the global workflow within the project. Arrows show how the outcomes of each WP are used in the subsequent step (Cf. Annex1 for a more detailed description of the WPs).

Plant Research International (PRI) is responsible for the work package 3 and is led by Dr. Hein Korevaar. PRI takes the lead of the task 3.1 as well. "WP3[10] will rely on established long running experiments and local initiatives to collect data. It plans to study the flows of feed, energy, nutrients and carbon at district level[11] and get reliable information about farmers' and other relevant stakeholders experiences. These data will be used later on in WP4 and WP5 for an assessment of the environmental and socio-economic impact of mixed farming systems'' (CANTOGETHER, 2011).

Figure 1: Overall workflow and interaction in CANTOGETHER



Source: CANTOGETHER, 2011

In line with the objectives of WP 3 to test and validate technical performances of innovative MFS at the district and landscape level, task 3.1 develop a common methodology for data collection and analysis of MFS (Figure 2 details the objectives and outcomes expected in WP3.1.). The task has been carried out in partnership with CropEye (Consultancy company for innovative networking among farmers, The Netherlands), ACTA (Association for Technical Agricultural Coordination, France),

[10]WP3 is aimed at testing and validating mixed farming systems at the district and landscape level through four steps: 3.1) Development of a methodology to study and compare mixed farming systems at the district level; 3.2) GIS and spatial model to assess and improve the financial, social and environmental impacts of material exchanges between farms; 3.3) Identification of main advantages and gaps of existing innovative mixed farming practices and systems at the district level; 3.4) Implementation and testing new innovative mixed farming practices and systems at the district level identified in the WP1

[11] A district is defined as an administrative entity. For instance a "departement", a region or a province.

INRA, TEAGASC, IUNG and FDEA-ART. The methodology will be adjusted according to data availability as well as their spatial and temporal resolutions but also taking into account the various biophysical and socio-economic realities of each case study. Thus, the methodology created in WP3.1 has to be valid for all of the sixteen regional level case studies in Europe and provides parameters enabling comparisons of farms within each region in order to identify differences between specialized and mixed farming systems and comparison between regions themselves, to enable increased insight into the reasons for successful or unsuccessful implementation. Two case studies, in France and in the Netherlands, are the basis of my work on which the methodology is tested. This thesis has been designed to be relevant for Mr. Hein Korevaar to get a more accurate idea of modelling issues, data availability and indicators suitability to compare farming systems. It could also be used by other persons involved in the CANTOGETHER project, within WP3 or other work packages, particularly WP4 and WP5 with in-depth realization of environmental and socio-economic assessment of innovative mixed farming systems. Nevertheless, I went my own way with the best understanding I could get from CANTOGETHER, and not all parts will be useful for the project[12].

Figure 2: Objectives and outcomes of Task 3.1

The following activities are planned to develop a common methodology (harmonized set of technical specifications for all regional case studies) to analyze, evaluate and forecast:

- The performance of mixed farming systems on landscape level or district scale in comparison to conventional innovative (specialized) farming systems.
- The potential for and efficiency of different methods of recycling and biomass conversion in a district;
- The changes of land use and land cover by mixed farming systems in agricultural landscapes.
- Ecological and economic impacts of sustainable energy crops.

The expected outcomes to reach these objectives are:

- A harmonized and tested methodology to compare and analyze the outcome of mixed farming systems at the district level.
- A harmonized set of parameters to measure the side effects of mixed farming systems compared to specialized farms for landscape, biodiversity and land use change.
- Better understanding of land use changes on soil organic matter content.

Source: CANTOGETHER, 2011

The objective of my work was to develop a methodology based on social, economic and environmental indicators at farm level and evaluate its efficacy in comparing sustainability of mixed

[12] Annex2 give a definition of agroecology and explain how this thesis fits as an agroecological research.

farming systems with specialized systems with particular reference to their impacts at landscape level. The results of this task enable to get a preliminary glimpse of farming systems in a region and determine the direction towards which innovation could be directed. The first part brings to light historical background that gives relevance and context on which the study relies and the research objective developed. I pay particular attention to introduce sustainability as it is of interest to me but also of relevance for the CANTOGETHER project. Then, the investigation include i) identification of major objectives and sub-objectives of sustainable farming systems according to CANTOGETHER; ii)identification of criteria for and selection of indicators of goal achievement; iii)design of typical farms that match the reality in two case regions of CANTOGETHER (Winterswijk in the Netherlands and the Ribéracois in France); iv)application of indicators for ex-ante sustainability assessment of mixed and specialized farming systems and v)evaluation of the quality of the chosen indicators and the efficacy of the methodology as a potential tool for supporting a development at farm and landscape levels towards greater degree of sustainability. The primary objective of the last part, and of the thesis as a whole, is to debate on the methodology and suggest some conditions for validation. Its scientific soundness and usefulness is assessed and some propositions for further testing of the methodology are presented.

1. FROM HISTORY TO CURRENT CHALLENGES

1.1. History of agriculture in Europe

1.1.1. The evolution of agriculture in Europe

Agriculture in Europe has changed dramatically over the past decades. In the first half of the 20th century, agriculture was characterized by high numbers of small mixed farms and a consistent number of farmers. Family farming for subsistence dominated the rural areas of Europe (Oomen et al., 1998). The common agricultural policy (CAP) was created after the Second World War, promoting production and market oriented agriculture to dispel hunger out of Europe. The focus was held on efficient agri-production systems characterized by a high degree of specialization, narrow crop rotations, and application of high external inputs of chemical fertilizers, biocides and feed-stuffs (Oomen et al., 1998). To achieve economic efficiency, a fundamental strategy for the development of the industrial model is to specialize, routinize and mechanize agricultural production (Ikerd, 1993). In the 1970's, mechanization became the prominent technology to the detriment of agronomic practices (Altieri, 1989) and the conventional model of agriculture based on bought inputs started to develop.

This emergent agriculture reflected an industrial development model considering farms as factories and field, plants, and animals as production units (Ikerd, 1993). Large-scale systems have emerged, contributing to a massive food production as well as the appearance of resource scarcity, environmental degradation, population growth, uncontrolled economic growth, social marginalization etc. (Altieri, 1989). Global agricultural development has focused on increasing productivity rather than promoting a more holistic integration of natural resources management (IAASTD, 2008). Although a significant increase in yields has been reached, these industrial strategies rose up substantial environmental, economic and social concerns for our societies (Ikerd, 1993).

In nowadays mainstreamed agriculture[13], farmers use large amount of external inputs to realize high outputs while decreasing working units' costs per hectare and increasing waste production (Van Keulen and Schiere, 2004; Meerburg et al., 2009). Mechanization has enabled farmers to save money with scale economies, farm bigger surfaces of land and to access new markets. Concomitantly, the rural landscape of Europe has been changed markedly by the development of mechanization and specialization. Intensification, landscape homogenization, natural habitats fragmentation and erosion of biodiversity (Meerburg et al., 2009) has led to an increasing concern for agriculture to redefine its relation with nature and global resources. The beginning of the 21st century in Europe shows a uniform countryside with many problems.

[13] Synonymous of conventional agriculture described as highly specialized, capital intensive, heavily dependent on synthetic chemicals and other off-farm inputs (Schaller, 1993) and inserted in a worldwide market-driven economy.

Farming practices during this period of industrialization not only had an impact on agroecosystems but also on natural ecosystems (Darnhofer et al., 2010). Importing inputs such as feed or mineral fertilizers and exporting production as well as slurry or manure over long distances affects the nutrient and energy balance of agroecosystems. Farmers in developed countries are reaching a point where further improvement of their systems following the path to globalization may become uneconomical, too risky, or inconsistent with the environment (Rodriguez and Sadras, 2011). Moreover, society expects agriculture to minimize inputs, improve quality of products, preserve the environment, and more generally, to take the path toward sustainable farming systems (Girardin et al., 1999).

1.1.2. The advent of sustainability

In the 1960's, at the peak of the green revolution, feeding the population was the central idea and there were very low concerns about the proper management of natural resources and the emergent alarming signs of resource depletion such as soil or biodiversity erosion (Brady, 1990). With the oil crisis of the 70's, industrialized countries discovered to what extent agricultural production was relying on purchased inputs and fossil-fuel energy. During the 1970's and 1980's, various sectors of societies throughout the world realized the many drawbacks threatening long-term development of humanity and recognized, among others, the need to bring environmental and social adjustments to conventional agriculture (Edwards et al., 1993). The major concern about energy efficiency has extended to natural resources and environmental preservation and induced the development of agricultural sustainability (Douglass, 1984 cited in Altieri, 1989).

Agroecology has emerged to support the development of sustainable agriculture and overcome new challenges facing agriculture. Solving this new issue of sustainable agricultural production and development has been the primary concern of agroecology, which provides a philosophical and practical foundation to deal with sustainability matters (Ikerd, 1993). Moreover, since changes in agriculture are inextricably linked to other developments in society (Schiere et al., 2004), more appropriate innovative methods and approaches are needed. The Agenda 21, which was adopted at the United Nations Conference on Environment and Development (UNCED) Earth Summit held in Rio de Janeiro in 1992, marked a turning point to reach sustainability and reconsider worldwide environmental and development issues. Ten years later, the World Summit on sustainable development was held in Johannesburg and represented a milestone in the development path of humanity for the 21st century toward more "sustainable societies".

1.1.3. Current challenges facing European Union

The main challenges of today's agriculture include the increasing demand for animal products, driven by population growth, changing diets, increasing incomes and urbanization (Van der Meer, 2008). The pressure on biomass to feed animals increases with the expending competition for food, feed, fertilizer, and fuel for this biomass (Herrero et al., 2010). Human population growth fosters the competition for natural resources such as soil and water with other sectors such as urbanization, infrastructure development or industry settlement (OECD, 2010). Also agricultural production, deeply embedded in tradition and in search of profit, is closely related to the issue of climate change concerning greenhouse gas emissions, environmental pollution and the depletion of earth's natural resource by damaging ecosystems (Eurostat, 2011). To produce food while maintaining biodiversity and ecosystem services is one of the greatest challenges facing Earth's population (Millennium Ecosystem Assessment, 2005).

There is an evident need for finding new production systems that are socially acceptable, economically viable and environmentally sound for people, farmers and nature (Ikerd, 1993; Meerburg et al., 2009; De Schutter, 2010). This means responding to basic needs and bringing about a better quality of life while at the same time minimizing the consumption of natural resources (Eurostat, 2011). In line with this declaration, livestock production systems should be linked with environment and seen from human, economic and political aspects as well as from the perspective of the utilization of natural resources (Steinfeld et al., 1995). A good balance between animal and crop production intensity and land uses must be found at local, regional and national levels (CANTOGETHER, 2011) in order to meet our imminent production needs.

Thus, production[14] systems should address social and economic development within the carrying capacity of ecosystems, and decoupling economic growth from environmental degradation (Eurostat, 2011). Agriculture must not compromise the ability of future generation to satisfy their needs (De Schutter, 2010). One of the aims of the European Common Agricultural Policy (CAP) after the reform in 2013 is to make the policy fairer, greener, more efficient and effective, understandable and able to offer more services to the public than only food production for European citizens (EC, 2011). Food supply for the European population, basic income and profit for farmers, employment in rural areas, biodiversity in flora and fauna, an attractive landscape and appropriate welfare for humans and animals should not be hampered (Oomen et al., 1998; De Schutter, 2010). The CANTOGETHER project is an attempt to respond to these challenges in Europe.

1.2. Identification of current issues and knowledge gaps in agriculture

1.2.1. The relationship between man and nature

The current challenges of the 21st century encompass all issues that impede our understanding of the link between human and nature. The profound dichotomy existing between western societies and ecosystems remains a relevant issue nowadays and of paramount importance in agriculture. The

[14] And consumption. However, it is beyond CANTOGETHER scope.

supposed superiority of human being over nature, relying on a techno-industrial philosophy of agriculture (Ikerd, 1993), is an underlying perception which has had marked effects on how we develop societies and manage ecosystems.

Bridging the developmental gap in agricultural evolution between current reality and ideology is guided by our visions (Harwood, 1990). Therefore, the perception that the human is at the centre of the universe[15] has led to a major misunderstanding of nature and therefore to misconceptions of our farming systems. What is the legitimate space human may take in ecosystems and how should humanity and nature interact in agroecosystems? How can we rely upon natural resources without depleting them in order to ensure tomorrow's productivity? These questions are increasingly brought to light with growing concerns about the environment. The sustainability of our development on earth seems to become uncertain as extreme weather events occur and various problems remains such as food security, food sovereignty, underdevelopment, social fragmentation etc.

Natural resources support human life on earth by sustaining the structure and function of our agroecosystems with their many social and environmental interactions. Matching tomorrow's demand for food and energy will entail the development and application of new scientific approaches and innovative solutions (Rodriguez and Sadras, 2011). Natural sciences and other sciences must be integrated with multi- and trans-disciplinary research in order to transform and transcend our understanding of these disciplines (ICSU, 2010). There is an urgent need to "diversify and strengthen Agricultural Knowledge, Sciences and Technologies (AKST), recognizing differences in agroecological, social and cultural conditions" (IAASTD, 2008) in order to reshape human interactions with the earth system.

1.2.2. Issues linked to sustainability

As stated by the International Council for Science (ICSU), devoted to international co-operation in the advancement of science, "we know enough to state with a high degree of scientific confidence that without action to mitigate drivers of dangerous global change and enhance societal resilience, humanity has reached a point in history at which changes in climate, hydrological cycles, food systems, sea level, biodiversity, ecosystem services and others factors will undermine development prospects and cause significant human suffering associated with hunger, disease, migration and poverty. If unchecked or unmitigated, these changes will retard or reverse progress toward broadly shared economic, social, environmental and development goals." (ICSU, 2010, p.5). Individuals' interests and benefits should be put in the background to face issues such as poverty, climate change or food security. This requires the adoption of collective agreements, to engage concerted actions and

[15] Anthropocentric world view has been dominant during the industrialization era in the western world (Verhagen, 2008), contributing to the development of an industrialized agriculture.

governance across scale and beyond geographical and cultural boundaries (IAASTD, 2008). From a more academic perspective, the walls between disciplinary fields, reinforced during the last century need to be dismantled to find new, innovative ways to reach real-world solutions (Naylor, 2011).

Human kind needs to find new ways of knowledge production and decision-making to cope with sustainability issues (Lang et al., 2012). Sciences used to be separated according to our methods for inquiry and calculation and the specific tools used in this field. However, knowledge that disciplinary sciences provide to make differences between things seems to be insufficient to respond to complex problems that require to study the process or the way things are organized (Klir, 1991). Sustainability science has emerged by the beginning of the second millennium, solution focused, community-based, inter- and trans-disciplinary, claims that empirical, participative and long term research is needed to provide a solid basis to achieve sustainable development (ICSU, 2010; Lang et al., 2012). Thus, research, extension and education should provide with the possibility to integrate scientific expertise in the field of sociology, agronomy, ecology, health and engineering to address pressing socio-environmental issues we are facing nowadays (ICSU, 2010).

In the field of agriculture, it is important to fundamentally shift our farming systems towards more environmentally responsible and socially just modes of production (De Schutter, 2010). However, this can only be achieved through citizen support and farmers' willingness to take on commitment to strive for sustainable development, and bridge actual knowledge gaps between social, environmental and economic parameters of natural resources management systems. The articles Lang et al. (2012) and Edwards et al. (1993) emphasize the importance to work on commonalities among ecosystems, that is biological diversity and nutrient cycling, in order to develop productive, stable and equitable sustainable agricultural system applicable to all regions. The latest consideration is a considerable challenge throughout the world but more particularly in Europe where harmonization is a key objective.

1.2.3. Challenges to farming systems

There is an urgency to produce accurate assessment of agricultural and natural ecosystems for targeted and well-planned adaptation action for agroecosystems management (Meinke et al., 2009). However, can our technical and technological potentialities enable us to provide safe water, maintain biodiversity, and sustain natural resources while minimizing the adverse impacts of agricultural activities on people and the environment? (IAASTD, 2008). To assess farming systems is not an easy task due to the complexity of social networks, the prominent economic reality as well as the lack of precise information describing ecosystems in which farming communities are evolving. Therefore, there is a need for the development of frameworks capable of integrating specialized knowledge and providing the possibility to manage them cross disciplines to address the challenge of agroecosystems' complexity (Funes-Monzote et al., 2009).

The current path of agriculture oriented towards industrialization and simplification represents an extra obstacle to sustainable development. As an example, to consider manure as a fertilizer rather than a waste product is hampered by the specialization and spatial separation of livestock and arable farms as well as the relative low price and ease to handle of mineral fertilizers (Van der Meer, 2008). Consequently, there is urgent need to develop environmentally sounds manure management practices in livestock production systems (Van der Meer, 2008). Additionally, the management of nutrient flows in cropping systems is an agronomic issue and it is important to consider the soil organic matter fraction instead of the soil nutrient solution. We need to promote a "farming of the organic matter" rather than a "farming of the soil nutrient solution" (Harwood, 1990, p.15) and that is where manure management becomes fundamental. Promoting on-farm biological processes management and closing nutrient cycles is a crucial step towards sustainable farming systems.

Mixed farming systems (MFS), integrating crops and animals, are well adapted to enhance on-farm fertility production and to reduce farmers' reliance on external inputs (De Schutter, 2010). Moreover, these systems have a close relationship with the agroecosystems and the wider regional context encompassing the pedoclimatic environment as well as the socio economic setting. Therefore, it is essential to set up locally adapted policies and practices for a proper development and implementation of MFS. Participatory approaches are essential to match innovation to stakeholders' intention and embed these new mixed farming systems in the community. One primary challenge for the mixed sector is to maintain an energy and nutrient equilibrium without compromising sustainable productivity growth (Blackburn et al., 1998). To prevent undesired impacts on the agroecosystem while sustaining the growth of the livestock sector, it is important to develop adequate measurements and produce references in Europe (De Haan et al., 1996)

Producing references throughout Europe is a large task and it can be partly done by developing models for reducing erosion or improving nutrient balance and energy flows for various multifunctional land use systems (Bruinsma, 2003). More generally, modeling these systems to assess their social, economic and environmental impact at different spatial and temporal scale and the scope for improvement is a challenge and can bring important benefits for further development and adaptation of MFS (Darnhofer et al., 2010).

1.3. Research question, scope and constraints

In line with this assessment, the goals of the research fit as a small part of the CANTOGETHER project but also deal with broader issues. Thus, the results of this research may be interesting in various disciplines for it bring insights on specific case studies but also on the process of setting up a methodology based on indicators.

> Set up a methodology based on social, economic and environmental indicators at farm level to compare sustainability of mixed farming system with specialized systems. The methodology should be a first step toward interpretation of impacts of different farming systems at landscape level in order to assess the potential for developing mixed farms in two case studies.

Starting from this objective, I set up a general hypothesis to be verified:

> It is possible to compare specialized and mixed farming systems with a chosen set of indicators in several case studies of Europe to study the potential of innovative mixed farming systems.

This research does not presume to fully understand and answer the issues and knowledge gaps presented in 1.2.1 and 1.2.2. concerning the sustainability of the relationship between humans and nature. These are too broad, too vague and not even completely understood by our most advanced research. However, the issues presented in section 1.2.3. about farming systems are of relevance and this thesis is an attempt to understand these challenges. It deals with the identification of solutions to cope with the undesired effects of farming systems on the path to specialization, while maintaining acceptable performances of these systems. Then, we consider the three aspects of sustainability from a farming system perspective in line with CANTOGETHER's objectives. The ecological aspect considers nutrient flows of nitrogen and phosphorus as well as biodiversity promoted on-farm. The economic aspect relies on the monetary value of production but also on the efficiency of natural and human resource use. Finally, the social pillar solely includes working hours per household.

The model should be valid for all regions of Europe and therefore be general enough to make use of simple data but accurate enough to make meaningful and relevant analysis and comparison of different systems within each region. An important point is to handle data heterogeneity and availability which will differ according to the case study's location. Thus, the methodology must be flexible enough to adapt to very different situations and the results are a first step towards understanding land use change and other processes at district level. These important constraints originate from the natural diversity existing within Europe but also from the design of the CANTOGETHER project itself, which builds upon existing case studies due to the limited amount of time and budget available.

2. MATERIALS AND METHODS

Materials and methods is usually a focused section which presents the underlying means used to answer the research question. This part presents extensively the inquiry process of my research which is an important basis for discussion. Because this thesis aims at establishing a methodology to compare mixed and specialized farms within the frame of CANTOGETHER, the inquiry process was not so strict and structured following a clear method. Nevertheless, certain reviews and frameworks exist in order to develop and validate methodologies based on indicators, such as those developed by Bockstaller and Girardin (2003) or Bockstaller et al. (2008). Based on the main principles and guidelines suggested by these authors, different concepts of interest are presented in this section. Table 1 synthesizes the contents of section 3 while organizing ideas according to the type of information used, that is physical or conceptual, how to link them together and for what purpose. In each situation the two levels of analysis, local and FADN[16], are differentiated. Finally, a definition of mixed farms according to CANTOGETHER is presented.

Table 1: Summary of the material and methods section

	Local level	FADN level
Physical inputs	Case studies	Databases
Conceptual inputs	Typical farms	Representative farms
Synthesis	Indicators	
Objectives	Assess potential for innovation	Compare case studies

2.1. Several databases for different purposes

Three types of data are used in the methodology. The first is available Europe-wide and is homogeneous throughout Europe from the Farm Accountancy Data Network (FADN) database. The second type refers to national databases which give data nationwide. The last kind of data is collected locally from expert knowledge and local surveys. Each level of data has a different accuracy and is the result of heterogeneous assumptions.

The FADN was designed in 1965 to assess economic impacts of European policies at farm level. It now surveys the entire range of agricultural activities carried out on farms throughout Europe of the 27. The European Union is divided into FADN regions, the sizes of which vary according to the country and its heterogeneity (FADN, 2012). FADN displays information about commercial farms, defined as “farms that are large enough to provide a main activity for the farmer and a level of income sufficient to support his or her family” (FADN, 2012). Basically, it concerns farms with an economic

[16] The Farm Accountancy Data Network and has its own spatial classification of European regions.

size, calculated in European Size Units[17] (ESU), which is greater than a certain threshold depending on the country (Cf. annex 3). In France and the Netherlands, the threshold has been established at €25,000 which excludes large areas farmed by “smallholders” in some regions. These farms are clustered at best resolution into 10 economic sizes and 14 farm types (Cf. annex 4).

Although the economic threshold which defines commercial farms is adapted to each country, the number of farms represented varies depending on the region and the country, as does the share of the total number of farms in the region. In addition, because only a sample of each farm type (FT) represents the entire class, some groups of farms within one particular region are under-represented compared to others. Farming sectors that are more professionalized and main-streamed are more likely to be represented, as it is shown by the difference between specialized arable and mixed farms. Also, most variables are expressed in economic terms rather than in terms of area or amount of products which can hinder proper environmental analysis (Andersen et al., 2007).

Nevertheless, using the FADN database allows the duplication of the analysis from one region of Europe to another region by using the same variables. This database will provide useful insights about commercial farming systems at the scale of an FADN region. However, these regions are often very large areas with heterogeneous pedo-climatic and/or socio-economic conditions. As an example, the Netherlands is one region but displays various soil types and farming systems. Thus, a cautious interpretation is necessary due to variable representativeness of the data in different places. Moreover, a proper investigation requires studying a set of farms in each case study area in greater detail.

Information from the FADN will be supplemented with data provided by national databases from smaller administrative districts in order to better depict the agricultural sector and the structures of farms in that area. National databases, such as Agreste and the “Réseau d’information comptable Agricole” (RICA) or Farm Accountancy Data Network (FADN) in France or the Agricultural Economics Research Institute (LEI) and the Central Bureau for Statistics (CBS) in the Netherlands, are the level of reference which enables us to obtain complete information about farms, their structure, their production etc. National databases offer a homogeneous analysis of all subdivisions within a country. However, assumptions and thresholds might vary from one country to another and may create bias in the methodology. Table 2 summarizes some characteristics of these databases.

[17] The **European Size Unit** measures the Standard Brute Margin defined at the European level.

Table 2: Characteristics of Dutch and French national databases

Name	Description
Central Bureau for Statistics (CBS)	CBS considers all farms with an economic size greater than €3000 and gathers mostly economic and farm size data. Farms are classified into eight farm types and/or eight economic classes. It can display information at the scale of a commune.
Agricultural Economics Research Institute (LEI)	LEI considers 15 farming enterprises types. It analyses into greater detail and describes with a higher accuracy farm structure, production level, technical results, farming efficiency etc.
Farm Accountancy Data Network (RICA)	RICA is the French network for farm data collection. All data, general and more precise will be gathered by this network. It has been designed to assess farmers' income and the economic activities of farms and foresee political impacts on the farming sector.
Agreste	Agreste is the French database for agricultural statistics, assessment and prospective, and works out the data from RICA. Farms are classified at least into 18 groups according to their technical and economic activities and seven economic sizes.

Sources: Agreste, 2010a; CBS, 2010; FADN, 2012.

With the first two levels of data, European and national, we assume that it is possible to draw a representative portrait of farming sectors in an area, but which mostly concerns economic and farm structure data, such as farm size, production quantity, efficiency etc. Internal flows of products as well as environmental and sociological data are most likely to be absent of these databases. Thus, it appears necessary to gather local, site specific information in order to get a more complete picture of a case study.

Local data is the third and last level of information used. This is the most accurate level and represents well the practical situation. Often empirical, it refers to farmers' or local experts' knowledge and has indeterminate spatial validity. This information can be collected directly on-farm through interviews with farmers, observation and measurements, but also from local projects and databases. Extension agents, local researchers, cooperatives or associations are structures likely to detain such information. In France for instance, "Chambres d'agriculture" are local institutions (at the department scale) that are close to farmers, encourage initiatives, carry out projects and produce technico-economic references. To put it in a nutshell, this knowledge is very site specific, difficult to upscale and is laborious to gather.

Thus, for the purpose of my thesis as well as for the CANTOGEHTER project, only a targeted set of information from the field will be studied. Information about environmental impacts of farms is of particular relevance in the CANTOGETHER project and is an important consideration in this study. Often, the only way to get environmental evidence is to collect on-farm data. Additionally, in order to develop innovative farming systems and practices that are relevant for farmers embedded in their local context, site-specific information is of primary relevance.

In this study, local data has been collected during daily exchanges with Dr. Korevaar and other colleagues at PRI. I had several occasions to do fieldwork and gain experience in Winterswijk and other parts of the Netherlands. A field trip at INRA-Bordeaux gave me the opportunity to discuss with Benjamin Nowak, a PhD student working on nutrient fluxes in organic farms in the Ribéracois, and his supervisor Thomas Nesme, also involved in WP3. An interactive landscape tour and a few appointments with local stakeholders and researchers constituted the basis of the excursion. Globally, I had little field work and I did not collect any on-farm data. All data was gathered through expert interviews and databases.

Starting from these three sources of information to set up a methodology that would make reasonable use of them, I assert three working hypotheses.

In order to set up a harmonized methodology to study and compare farming systems in different regions of Europe it is necessary to use data from the FADN database.

Data from FADN are not sufficient to evaluate the reality in the field and the potential for implementing innovative mixed farming systems.

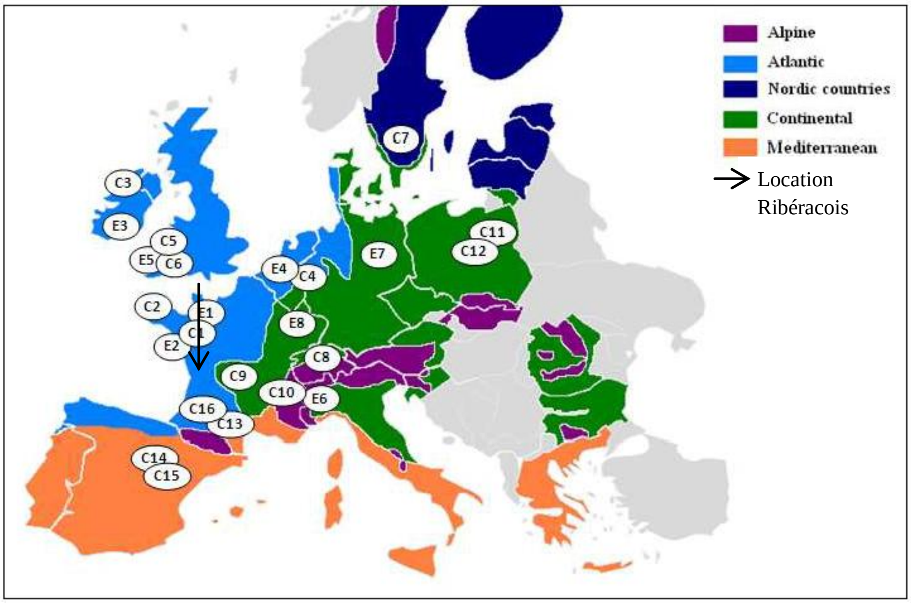
Site specific information about farms from measurements and experts interviews are the most relevant to understand farms in their local contexts and to design innovative systems.

2.2. Case studies

I investigate two case studies; C4, or the commune of Winterswijk in the eastern part of the Netherlands and C10, where I study one of the three areas, or the “petite région agricole” of the Ribéracois located in Dordogne (Cf. figure 3[18]). Both cases are described in this section following the same logic. First, the FADN region is presented, then a sub-area corresponding to an administrative district gives better insights on the context of the case study and finally, the case study in itself is described through its agricultural systems and major agricultural land use.

[18] C stands for Commercial farm and can be at farm or regional level. E stands for experimental farm.

Figure 3: Localization of the CANTOGEHTER case studies in the European biogeographical regions



Source: CANTOGETHER, 2011

These two cases fit in the development of the research question for different reasons. Being in the Netherlands, it is logical to work on the Dutch case study and both Dr Hein Korevaar and CropEye have been working for a long time in this area. Additionally, several colleagues at Plant Research International have practical experience in the municipality of Winterswijk. Numerous projects flourish in the municipality among people who are committed to developing and adapting agriculture to emergent social, economic and environmental issues. This commitment facilitates learning and exchange processes and enables to obtain information from farmers. The area, dominated by conventional milk farms with slurry surpluses, presents good prerequisites to study the possibilities for developing mixed farming systems at regional scale. Arable farms are present as well and need to fertilize their crops, hence, offering interesting potential for studying possibilities for material exchange between farms.

Located in Dordogne, the Ribéracois traditionally has a much diversified agriculture, many productions types being represented. Dominant types of farming systems include not only on-farm mixing, but there is also scope to explore potential exchanges of materials between specialized farms in the area. Additionally, it is easier for a French speaking person to investigate a case study in France and it may bring to light interesting insights for Task 3.1 to set up a harmonized methodology. Last but not least, the region has an interesting background in organic agriculture providing the study on conventional systems of production with alternative production systems. This last point is important to broaden the range of farming systems that will be studied and potentially up scaled in Europe, using alternative production methods and distribution networks.

2.2.1. The Netherlands, Gelderland and Winterswijk

According to FADN geographical classification, the Netherlands is one region even though we can find important variability of socio-economic conditions and soil types. Three types of soils dominate in the Netherlands: sandy soils, clay soils and peat soils which have very different characteristics and functions. Whereas clay soils have a good potential to grow crops, peat and sandy soils are mostly used for grassland. Thus, FADN region includes important heterogeneity.

In order to better consider the data from the FADN database table 3 shows the number and proportion of small and large farms. Almost 30 % of all farms have an economic size below €25,000. However, these 20,000 farms use only 7% of the total UAA and 93% of the UAA in the Netherlands is farmed by medium and large enterprises. Therefore, in terms of land use representativeness, FADN data gives a quite reliable analysis. Nevertheless, it may not be equally the case in all provinces and farming types of the Netherlands.

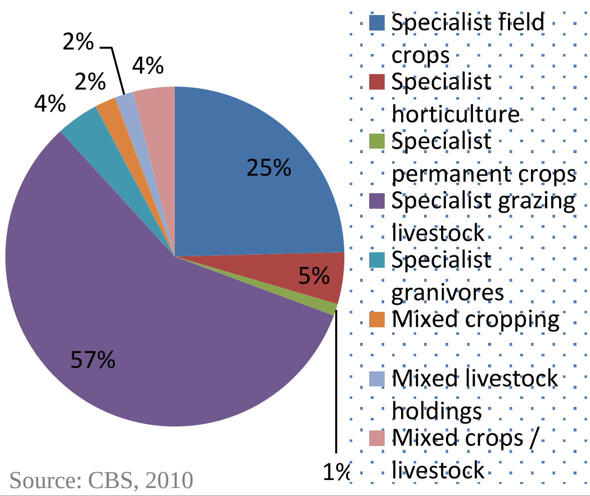
Table 3: Selected characteristics of the FADN region "The Netherlands" in 2010

	Small farms	Medium and large farms	All farms
Number of farms	19,950	52,365	72,315
Proportion of farms (%)	28	72	100
UAA (ha)	124,110	1,748,209	1,872,319
Proportion of UAA (%)	7	93	100

Source: CBS, 2010

Figure 4 shows the agricultural land use in the Netherlands. Around 70% of the UAA is used for grassland and maize fields principally for specialized dairy farms (Dairyman, 2012). One fourth of the area is used for field crops, mainly potatoes and sugar beets. Although specialized horticulture farms represent only 5% of the total UAA, their economic size is exceptionally important. Finally, mixed farms are very marginal and specialization has strongly occurred in the Netherlands.

Figure 4: Agricultural land use in The Netherlands



Source: CBS, 2010

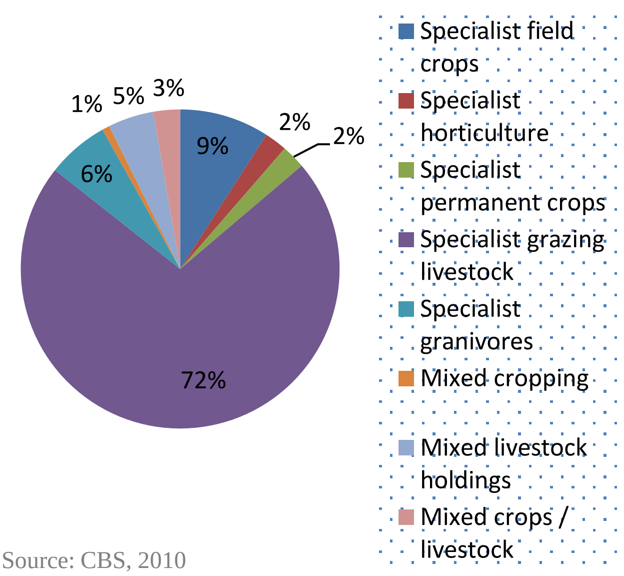
The Netherlands is divided into twelve provinces (Cf. annex 5). Gelderland is located at the center and eastern part of the country, sharing a border with Germany. Table 4 shows the proportion of small and large farms with their respective UAA in the province of Gelderland. Small farms are an important component of local dynamic and represent 33% of all farms and 10 % of the total UAA.

Table 4: Selected characteristics of Gelderland province in 2010

	Small farms	Medium and large farms	All farms
Number of farms	4060	8290	12350
Proportion of farms (%)	33	67	100
UAA farmed in ha	24,722	213,338	238,060
Proportion of UAA (%)	10	90	100

Source: CBS, 2010

Figure 5: Land use in Gelderland



Source: CBS, 2010

In terms of land use, Gelderland shows different specificities (Cf. figure 5). First of all, the importance of grazing livestock is striking. Approximately 7400 enterprises farm 72% of the area, most of which are dairy farms (CBS, 2010). Specialized field crops represent the second largest category with 9% of the UAA cultivated with potatoes, cereals and sugar beets. Other field crops are relatively marginal even though the economic size of poultry and pig is high on a small acreage. We notice also the scarcity of horticultural companies in Gelderland compared to the Netherlands. Finally, mixed farms are also scarce in Gelderland although mixed livestock farms are present in higher proportion (5% in Gelderland against 2% in the Netherlands).

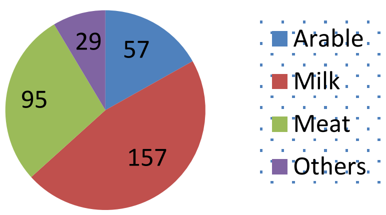
Located in the most eastern part of the Netherlands, along the German border, the municipality of Winterswijk is part of Achterhoek district, a sub-division of Gelderland province (Cf. annex 5). Mixed farms were dominant in the landscape for centuries and until the mid of the twentieth century. After the introduction of maize silage in the 60's, most arable fields have been turned into fields with silage maize, often in rotation with grassland. Arable crops decreased while grassland and dairy cattle increased. With the arrival of the quotas in the 80's, the production per cow increased concomitantly to a decrease in the number of cows and further specialization took place in dairy husbandry systems.

During the 90's, the area has been designated as "Valuable man-made landscape" and is registered as a "National landscape" since 2005 (Hein Korevaar in Interview).

Small plots with numerous hedgerows and scattered patches of forest depict most of the area. Sandy soils are the most present type with some peat on loam formed locally due to water retention table. Sand has also deposited at some places and most of the soil is sediment from the Rijn River. Several small brooks are passing through the region from east to west following a slight slope. Winterswijk is entirely above the sea level and dominates the Achterhoek from a small plateau. Ridges and ditches are imminently part of the landscape and small plots are encircled to manage excess of water (Cf. pictures annex 6)

The strong commitment of farmers and local organizations to strive for innovation toward multifunctionality makes of Winterswijk a dynamic and atypical area of the Netherlands. The region has all characteristics of a case study and is nowadays one of the pilot areas for the reform of the European Common Agricultural Policy (CAP) to study various options for farmers in offering environmental and social services to the community. Agriculture is directed towards a regional development of integrated multifunctional land use where nature, recreation and living are strongly intertwined (Korevaar and Geerts, excursion the 26th of June 2012).

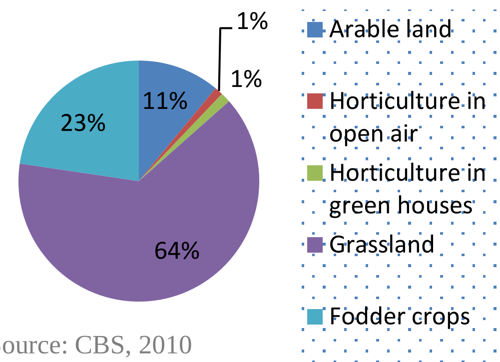
Figure 6: Number of farms of major production types in Winterswijk



Source: CBS, 2010

Around 344 farms maintain 8054 ha of UAA (CBS, 2010), most of which are dairy and meat farms with grassland and fodder crops, as it is shown in figures 6 and 7. The 64% of grassland includes 80% of permanent grassland. Alternatively, we can find a few arable farmers growing maize or potatoes, sometimes in partnership with dairy farmer to plough their grassland and strengthen their rotations. In addition to mixed farms, I chose to study dairy farms and specialized other field crops farms because they offer on the one hand excess of manure and slurries and one the other hand, a lack of nutrients and organic matter. Specialized arable farms are interesting to study because they produce straw that can be used for husbandry systems. However, FADN database do not displays data on cereals, oil and protein crops (COP) farms for the Netherlands because of a too small sample size.

Figure 7: Agricultural land use in Winterswijk



Source: CBS, 2010

2.2.2. Aquitaine, Dordogne and The Ribéracois

The FADN region "Aquitaine" is located in the south-west of France and is composed of five departments (Cf. annex 7). There is an important heterogeneity of climates, altitudes and soils. Many different systems are present, from conventional arable farms in the north of the region to very extensive sheep farms in the Pyrenees. Table 5 presents some general characteristics of the region.

Table 5: Selected characteristics of the FADN region "Aquitaine" in 2010

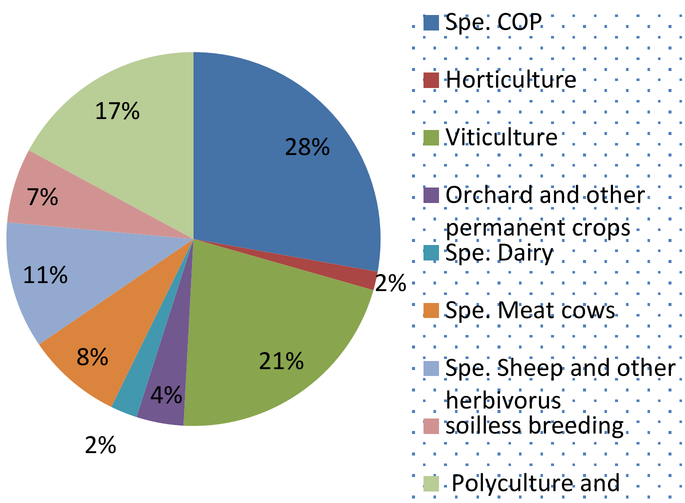
	Small farms	Medium and large farms	All farms
Number of farms	18,554	24,501	43,055
Proportion of farms (%)	43	57	100
UAA farmed (ha)	158,158	1,199,590	1,357,748
Proportion of UAA (%)	11.6	88.4	100

Source: Agreste, 2010a

In Aquitaine, small farms represent 43% of the total number of farms and occupy 11.6% of the UAA. Thus, small farms are important in the dynamic of rural areas and are more diversified than large farms (Agreste, 2010b). However, medium and large farms are leading the sector economically and have more decision power within the region. Besides, 3.6% of the UAA in Aquitaine is cultivated under organic farming which represents more than 50,000 hectares with a wide range of productions (AgenceBio, 2010). A total of 1700 farmers under organic agriculture represent 4% of all farmers in the region (Agreste, 2010b).

Figure 8 shows the large diversity of systems within the region, all farming type having different proportions of farm size. Although 28 % of the UAA is cultivated by arable farms, more than 20 % of the surfaces are occupied by mixed farms. It seems difficult to study farms at the regional level (Aquitaine) with FADN data only, and a smaller administrative entity such as the "département" Dordogne would be more appropriate.

Figure 8: Agricultural land use in Aquitaine



Source: Agreste, 2010a

Dordogne is located at the north-est of Aquitaine. We can find 462 farms under organic agriculture production, covering 20,516 ha (Agreste, 2010b). Although small farms only represent one sixth of the UAA they represent more than half of the total number of farmers in the department (Cf. table 6). All types of farms are classified together as organic farms and it is not possible to get specific data of one type of organic farm.

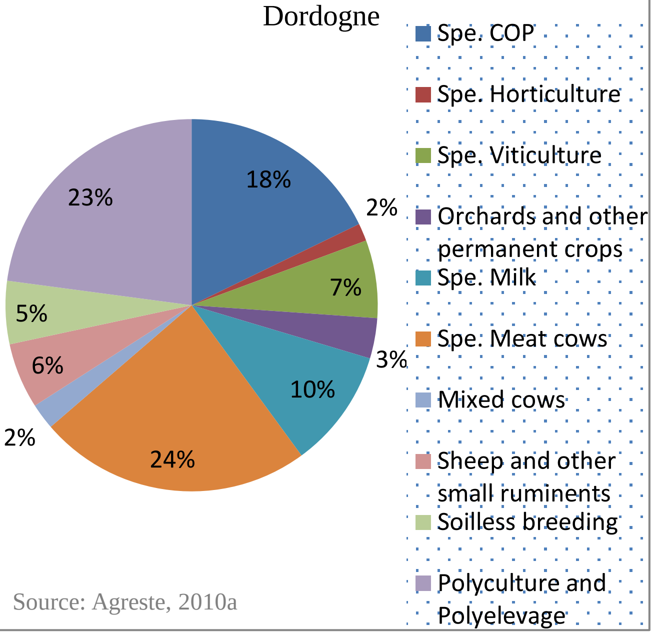
Table 6: Selected characteristics of Dordogne in 2010

	Small farms	Medium and large farms	All farms
Number of farms	4,517	4,166	8,683
Proportion of farms (%)	52	48	100
UAA (ha)	45,649	264,033	309,682
Proportion of surfaces (%)	15	85	100

Source: Agreste, 2010a

In 2010, Dordogne covers a surface of 922,500 ha composed of UAA (39%), forests (44%) and infrastructure and urbanization (17%) (DRAAF, 2010). The 309,700 ha of UAA, detailed in figure 9, are farmed by 8,683 farmers in 2010. It includes 178,000 ha of permanent grassland, 80,500 ha of cereals, 20,000 ha of vineyard and 11,000 ha of orchards (Agreste, 2010b). We can add 69.300 ha of wood land and other non-productive surfaces as well as 3000 ha of building (Agreste, 2010b). Overall, land use in Dordogne is much diversified.

Figure 9: Agricultural land use in Dordogne



Source: Agreste, 2010a

During the period between 2000 and 2010, half of the mixed farms disappeared. Whereas it represented one third of the total number of farms in Dordogne, it is nowadays less than a fourth of all farms (Agreste, 2010b). Half the jobs in mixed farms dropped off. Consequently, the succession of farm manager is ensured for large farms but jeopardized for smaller ones. Concerning specialized farms, while rearing activities such as pig, sheep or meat cows decline, the number of specialized poultry and arable farms rise up.

Dordogne includes 6 ‘Petites régions agricoles’ (Cf. annexe 7). The case study focuses on one Petite région agricole, “Le Ribéracois”.

The Ribéracois, located at the north of Dordogne counts 70 communes (Cf. annex 8). Soils are for a large part composed of shallow to deep argilo-calcareous marls. They are more or less adapted to arable production or cattle breeding depending on the topography. Slopes are maintained by cattle whereas plains or plateaus are cultivated with cereals (Cf. annex 9). In the Ribéracois, we find roughly meat cows and calves (Limousines) in the northern valleys, cereals in the plateaus and dairy and mixed farms in the south (Benjamin Nowak personal communication). The case study in the area involves only organic farms and 17 farms spread around the area have been investigated (Nowak, 2012). Table 7 presents an overview of the farming sector in the Ribéracois.

Table 7: Selected characteristics of the Ribéracois in 2010

	Small farms	Medium and large farms	All farms
Number of farms	404	412	816
Proportion of farms (%)	49.5	50.5	100
UAA (ha)	10,241	39,282	49,523
Proportion of surfaces (%)	20.7	79.3	100

Source: Agreste, 2010a

The number of small and medium and large farms is displayed to show the relevance of using FADN data. Half of the farms are below the economic threshold set by FADN and half above, considered as full time activity and revenue enterprises. Additionally, small enterprises farm one fifth of the UAA which is not negligible. They are important from a local dynamic point of view, and many of them sell a substantial part of their products through short food supply chains (Agrest, 2010)[19]. A more careful study of the dataset reveals that a large majority of meat and mixed farms are small enterprises.

Bottlenecks in organic agriculture are supply and distribution chains which have a strong influence on possibilities for farmers to farm organically or not. Local valorization of products and short food supply chains offer an opportunity to develop organic farming but they remain marginal. Cooperatives dealing with organic products are scarce and too far for cereals producers. Local cooperatives concerns goat milk (“Laiterie le chêne vert”), sheep milk (“Laiterie le petit basque”) and calves for meat (“Scale pervert”). Globally, farms are evolving toward specialization and rearing activities are often very restrictive and few incentive for young farmers to start.

[19] It is impossible to characterize land use in the Ribéracois because data in Agrest are not displayed at this level. It was only possible to get a limited amount of information by selecting myself communes constituting the petite région agricole.

In the analysis, we consider three important farming systems: specialized goat milk production, specialized arable farms and mixed farms. The last category includes among other goat farms with additional activities.

The fact that the two locations present very different socio-economic and pedo-climatic conditions, are of different sizes and work with different productions systems, create the relevance of studying them both. In order to create a harmonized methodology and identify the barriers that impede the selection of a finite set of indicators, having very heterogeneous cases is of utmost relevance. Also, it brings important insights on data availability and the use of various databases in two different countries of Europe.

2.3. Definition and objectives of typical and representative farms

Throughout the study, data is never displayed from one farm in particular, but rather the average from a group of farms or farm typology (Cf. definition in annex 10). According to the Council Regulation 79/65/EEC (FADN, 2012) it is prohibited to display farm data for privacy reasons. Therefore, farm data is available only under an aggregated form, which may contain a significant variety of inter-farms differences. The distinction between representative and typical farms rely on the type of data considered and the selection criteria used to create farm typologies. Associated with the bias of aggregation and disaggregation of data (Feuz and Skold, 1991), the distinction between typical farm and representative farm is crucial for our study. Table 8 describes both concepts.

Table 8: Concepts of Typical and Representative farms

	Typical farm	Representative farm
What	Modal concept	Statistical concept (mean-variance or average)
How	Selecting characteristics from a group of farms with expert knowledge	Averaging data from a group of farm from FADN and national databases.
Why	Used to give advice to farmers	Used for instance to analyze public policy effects on different types of farms
Strengths and limitations	Very site specific	Large area covered

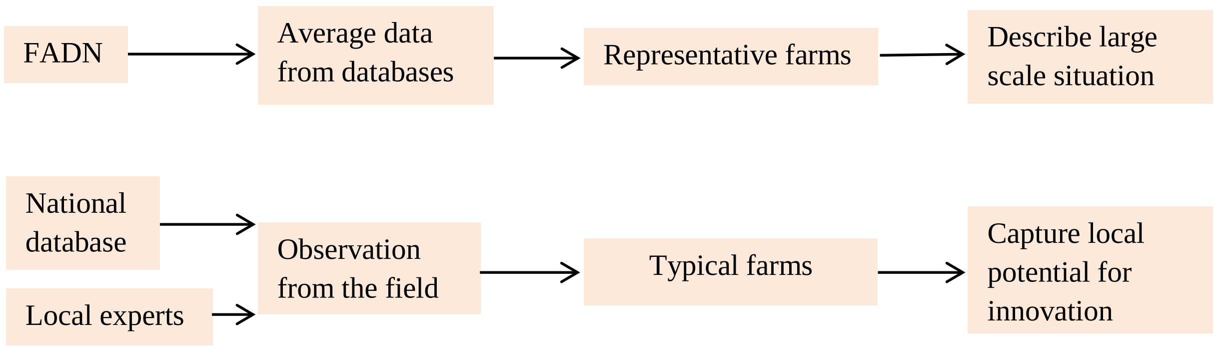
Source: Adapted from Feuz and Skold, 1991

Typical farms are based on experts' knowledge but it is possible, if necessary, to use average data from national or regional databases, once checked by experts, to complete the profile. Typical farms are site specific, they match the actual management practices of farmers, available labor and machineries and conform to the physical constraints of farms. In addition, it is assumed that farms react similarly to innovative practices or technologies (Vayssières et al., 2011). "The need to synthesize the diversity of farming systems and to evaluate them in a holistic manner makes the typical-farm approach a useful procedure for much of sustainable-farming research "(Vayssières et al., 2011, pp. 147). Moreover, these farms are the basis upon which innovative practices are designed. However, their construction is laborious and the level of detail depends on available time and budget of CANTOGETHER.

Representative farms are represented by the 14 farm types of FADN, defined according to the proportion of income originating from each production, calculated in terms of standard gross margin (Andersen et al., 2007). Farms are then grouped and the FADN database displays only group averages of a sample of each farm type. It is no longer a question of real farms but of statistical groups of monetary farms representing all other farms. Thus, the clustering method used in FADN provides a limited scope for analysis, which might not suit the objectives of CANTOGETHER. However, a great advantage of this concept is that it enables compilation and analysis of data with classical statistical tools, and therefore works at a higher hierarchical level.

Farm typologies are necessary to present, combine and synthesize farm management indicators. They offer a tool to assess the farm management indicators as an integrated set rather than as a single indicator (Andersen et al., 2007). Figure 10 shows how the two concepts of typical and representative farms are used to create a two-scale methodology.

Figure 10: Concept of typical and representative farms in the CANTOGETHER context



The concept of representative farm enables us to obtain a rough idea of the farming sector in a given FADN region of Europe. All European countries apply the same methodology to render information about the size of farms, structure and accountancy. The concept is used to get a first homogeneous analysis and notice certain trends and patterns within a region. Additionally, it can be used to compare regions and countries against one another. The concept of representative farms applies homogeneously throughout Europe at a large aggregation level. The reason for separating typical and representative farms is the incapacity of FADN to provide sufficient information to examine farms possibilities to implement "environmental innovation[20]".

[20] Innovations in CANTOGETHER from the description of work document are mentioned as follows: "[...] the implemented innovations at district level will consider likely transportations of matter (wastes, feed), sharing of

On the other hand, typical farms allow the researcher to be closer to field conditions when assessing farming systems in the two case studies. They are defined with expert and local people knowledge to better depict the reality in the field. Hence, typical farms show the gap between information from databases and real world situation. It would not be possible to cope with practical issues if only considering FADN. Above all, they will serve as a basis to assess the potential for implementing innovative mixed farms and farming practices.

It is interesting to notice that information from national databases is used solely to consolidate local descriptions of farming systems and the concept of typical farms, instead of using this data to support FADN data. It is more important to emphasize typical farms than representative farms in this project and the precision of their description is primordial. Nevertheless, it would be relevant to compare national data with FADN to evaluate its accuracy, but also to articulate the two different levels. This last point is discussed in further detail in section 4.7.

2.4. Using indicators: classification, sources and interpretation

Linking theory and practice is a challenge that science faces from its earliest experiments and which still remains today. The gap between our practical and conceptual world is still wide and blocks the development of methodologies which are consistent with real world situation. Presently, indicators[21] are the bond to bridge this gap. At each level corresponds a farming system theory. In the first place, real farms and practical matters are synthesized in the concept of typical farms. Whereas average commercial farms data will be clustered with the concept of representative farms. Indicators can provide an infinite number of possible interpretations and the two above-mentioned concepts will be the underlying basis for interpretation of output information. Indicators are appropriate tools to compare farming systems, interpret the potential to develop innovative mixed farms and vulgarize results to communicate about the project.

Gathered and integrated in a coherent methodology, a selection of indicators is tested in two case studies. The whole methodology should be coherent with other tasks of WP 3 but also with the entire CANTOGETHER project. This issue is discussed in section 4.7., relying on the outcomes of the WP3 workshop held in Wageningen on the 26^{th} and 27^{th} of June[22]. Additionally, to design a harmonized methodology, we will test the aptitude of indicators to fit very heterogeneous pedo-climatic and socio economic conditions.

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land between areas dedicated to cash crops, to feed crops, to renewable energy production and to ecological areas. (CANTOGETHER, 2011)

[21] A general definition of indicators is presented in annex 11

[22] It was decided at the kick of meeting of CANTOGETHER held in Rennes beginning of March 2012, to organize a workshop for WP3 in Wageningen end of June. The first deadline, Task 3.1 delivers a methodology at month 6. Twenty participants from all tasks and sub-tasks of WP3 met during a two days workshop. I had the opportunity to give a short presentation and rise up some elements for discussion.

Two different visions of sustainability can be distinguished: a goal-oriented vision based on a set of objectives, as adopted in the CANTOGETHER project, contrasting with a property-oriented vision based on systemic properties of a system (Bockstaller et al., 2008). This latter vision is used for in methods such as the multiscale methodological framework from López-Ridaura et al. (2005) and provides in-depth insights on community goals and leverages for action. However, it does not match the purpose of the assessment in task 3.1. Instead, CANTOGETHER relies on a set of objectives and goals to be reached in response to the call of the European commission and with the time and budget available.

The literature includes a wealth of indicators and ways to make typologies according to their subject, objectives, scales, data used and specificity. It is interesting to have a general definition of indicators according to the source of data because the methodology relies on two scales associated with different types of data: a global scale at the FADN regions level and a local scale at municipality level. From this assumption, the work of Bockstaller and Girardin (2003) defines two wide categories of indicators. The first type involves the simple indicators resulting from measurements or estimations, using models of variables. Those are more likely to be present in the local assessment. The second type is called the composite indicators and is obtained by aggregation of simple indicators. Most FADN variables are aggregated or will be aggregated into composite indicators in the methodology.

To study the sustainability of farming systems, we are going to use three sorts of indicators, this time defined in line with their specific matters and objectives. Economic, environmental[23] and social indicators are selected to suit the economic, environmental and social goals of CANTOGETHER. Each of these categories of indicators may be defined more precisely depending on the type of assessment, the scale considered, the data available and the objectives to reach.

- Economic indicators: principally make use of FADN data to be applied at regional scale and throughout Europe. These indicators are used to compare farming systems with one another as well as to compare countries and case studies. However, FADN's farm typology is based solely on farms' gross margin.
- Agri-environmental indicators: make use of locally collected data and apply to small areas. They are site specific and are used to assess and compare the impact of different farming systems on the landscape. These indicators are important to consider in order to upscale a farming system analysis to a district analysis because they consider farms in their environments with their many interrelations.
- Social indicators: are very scarce and have in fact barely been taken into account. The only social parameter conserved in this methodology is the revenue of farm family workers from

[23] For more clarity, environmental indicators referring to local agricultural assessments are called agri-environmental indicators.

FADN. However, it may be considered as an economic indicator and no other variable will indicate further involvement with the community, access to information, local dynamics etc.

I do not develop new indicators, and I follow common principles and methodology from the work of Girardin et al. (1999) and Bockstaller et al. (2008) to validate them. All information is computed in an Excel file to analyze case studies by composing a set of indicators aimed at comparing mixed and specialized farms. This methodology, being the purpose of this study, should provide the better insights on how to analyze case studies and how to use various sorts of data.

As suggested by the above-mentioned authors, developing an indicator involves several steps. The first step is to draw out underlying objectives from the CANTOGETHER proposal that suit the purpose of the project and identify end-users of the methodology. This constitutes the core assumption on which the thesis will be built. These objectives are then broken down into sub-objectives that add clarity and precision as for the main goals. Then, starting from sub-objectives as well as from existing data available in databases and in the field, criteria are defined as a possible way to evaluate these sub-objectives. Indicators are then selected from literature and from databases to calculate these criteria.

Once all objectives and sub-objectives from the CANTOGETHER proposal were expressed by an indicator, I selected a few of them to be tested on the two case studies. Several parameters influence the selection of indicators. First, according to the firsts two working hypotheses (Cf. p.15) data from the FADN database are necessary but not sufficient to describe the reality in the field. Therefore, I selected indicators that make use of both levels of data, regional and local, in order to balance the analysis. Secondly, to assess the extent to which objectives of CANTOGETHER are reached, I selected indicators derived from all 4 major objectives. Thirdly, economic, social and environmental indicators are selected in order to obtain an analysis that satisfies a sustainability perspective. This last point may be controversial since most indicators are based on economic data and very few social indicators are displayed. Additionally, existing indicators from reliable sources are favored because they are already tested and trusted. Indicators have to fit available data or manageable collection of information. Thus, major references at the FADN level include the FADN database and the IDERICA framework (IDERICA, 2004). Besides, the DIALECT method (Solagro, 2011) provides good references at the local level. Finally, to complete the design process of an indicator, one should operate various tests to certify the sensitivity, specificity and acceptance of an indicator as show by figure in annex 12 (Girardin et al., 1999; Bockstaller and Girardin, 2003). Even if most indicators originate from pre-existing methodologies, their relevance has yet to be tested.

The IDERICA framework is an extension of the IDEA ("Indicateurs de Durabilité des Exploitations Agricoles" or sustainability indicators of farms) method originally designed to assess the sustainability of farms in France. Later, this methodology was enlarged to characterize sustainability of farms at national level and describe trends at regional level. Thus, IDERICA makes use of the RICA database, acronym of "Reseau d'Information Comptable Agricole" or Farm accountancy data network as well as the Agricultural Census (IDERICA, 2004) and consequently relies on FADN farm typology.

The DIALECT tool (DIAgnosis Linking Environment and "Contrats territoriaux d'exploitation" (CTE) that was the first European agri-environmental subsidies distribution scheme in France), has been designed with the impetus given by the Rio conference in 1992 to provide an agri-environmental diagnosis tool. The first version was created in the south of France in 1995 by Solagro and evolved until its most recent update in 2011. It is a synthetic and easily applied method to assess the environmental impacts of farming systems, to determine ways for improvement and to suggest advice to farmers (Solagro, 2011). DIALECT supplies a rapid and global evaluation of the environmental risks of the farm (Halberg et al., 2005).

In order to interpret responses given by each indicator, a reference value is chosen. It might be a norm, a threshold or a target expressed in an absolute or relative way (Bockstaller et al., 2008). Due to the subjectivity of an absolute value and the important heterogeneity of regions throughout Europe, the use of relative reference value is preferred. Thus, values are specific to each case study in order to compare farms between them without judging their absolute quality. For the set of indicators using data from FADN, reference values are designed with the same set of data. Values of reference taken from representative farms refer to means for one or several variables from the FADN database in a given FADN region. Values for one farm type are compared to values for all farm types, sometimes with the exclusion of some groups. This decision is very subjective and I could have used medians instead. However, since FADN displays solely average data from a sample of farms, I judged it more appropriate to use an average value rather than a median value. At local level, I do not settle reference values for typical farms and indicators outcomes are interpreted with "expert knowledge". It is often difficult to balance the several perspectives one can have on the indicator. Nevertheless, it might be the most reliable technique available, along with farmer judgment. The interpretation of these figures is ambiguous and is discussed in more details in section 4.5. as well as the possibilities for using average values at FADN level and benchmarking[24] at local level.

[24] Benchmarking is the process of improving performance by continuously identifying, understanding and adapting outstanding practices and processes found inside and outside the farm (EEA, 2001).

2.5. Basing the methodology on indicators: scales, objectives and criterions

The set of indicators selected to compare farming systems are to be useful primarily to researchers of the CANTOGETHER network. The project being in its early phase, these indicators are a way to understand and compare beforehand what is the potential for implementing mixed farms in the two case studies. Extension services and SMEs may use it as well in this way. As suggested by Bockstaller et al. (2008) table 9 shows end-users functions in the methodology. It is important to notice the absence of farmers in table 9 as the study does not aim at direct dissemination to farmers, but rather at paving the way for researchers.

Table 9: End-users of the methodology

Make the calculation	Use the results
- CANTOGETHER researchers - Extension services	- Policy makers - SMEs - Researchers

Ranging from a single plant to a watershed, the choice of a relevant spatial scale depends on the study carried out and on expected results. An agroecological approach is broad ranging in its analytical units despite the fact that agroecosystems are considered as the inherent level of analysis and the plot level as the most relevant scale for action (Altiery, 1987). Farm level might be preferred to deal with sustainability issues for it is possible to understand the interplay between decision making and socio-economic and biophysical constraints (Girardin et al., 2000). Additionally, many data are available only at the farm level.

In the context of CANTOGETHER, and in order to study opportunities at regional scale to develop between farms mixing, it is important to keep farm boundaries flexible to a certain degree. This type of relation may entail the consideration of two farms at a distance from each other to be “one entity”, or at least that we consider several farms as fulfilling the same objective (the definition of mixed farming systems according to the CATOGETHER project is given in the following section). Ecological focus areas are another example of practices that require studying the relation of farms with the larger ecological environment. As an example, a watershed or a soil type might be a relevant scale to consider studying water and nutrients movements as well as erosion processes. Similarly, departmental or regional scales defined by administrative boundaries are a favored level for economic data aggregation or to deal with political issues.

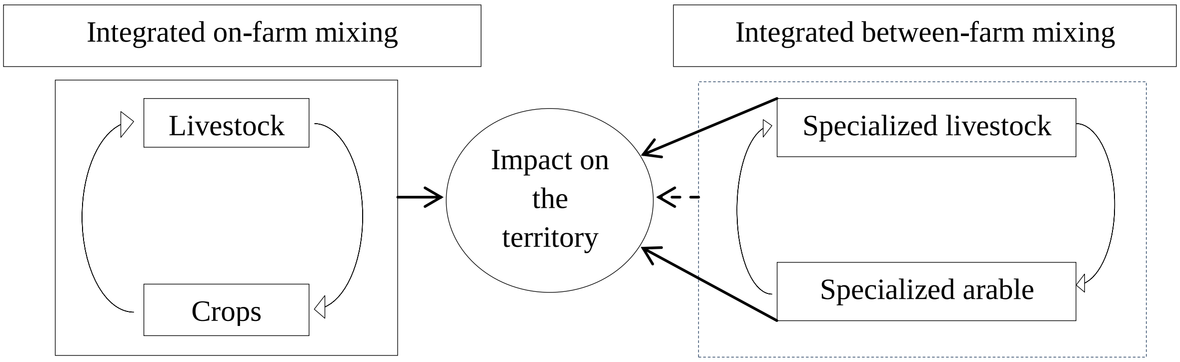
However, this thesis focuses on the comparison between farming systems within case studies and therefore considers the basic boundaries as the “farm gate”. In order to study influences of socio-economic factors on the resource based production system, farm level is most appropriate to deal with sustainability issues. Moreover, being the most adapted scale to study the economics of farms, the FADN database displays data at the farm level. Because a large part of the analysis is based on economic data from FADN farm gate boundaries remains relevant.

Concerning the temporal scale, an ex ante assessment is carried out in order to make a preliminary evaluation of possible future scenarios (Castoldi, 2008) while basing the analysis on data from one year only. At the scale of FADN region, data from 2009 will be displayed in the analysis for it is the most recent year displayed in FADN. When trends over several years are required, additional data from 2007 and 2008 will be used. Nonetheless, case studies description using national databases will make use of data from 2010, being the most recent complete set of data.

2.6. Definition of mixed farming systems

There are several ways of defining mixed farms, all of which being based on two main features (Schiere and Kater, 2001; Van Keulen and Schiere, 2004): i) on-farm versus between-farm mixing which differs only according to the scale we consider, farm or broader; ii) diversified versus integrated systems which describe the interconnectedness of the two systems. One last characteristic can be used and refers to mixing within crop and/or animal systems. However, we will define mixed farming systems only with the first two oppositions and the CANTOGETHER project considers a mixed farm *stricto sensus* as being an integrated on-farm mixing system (rearing animals and growing crops with important exchanges of biomass between the two endeavors). However, CANTOGETHER considers integrated between-farm mixing systems as well and is looking for possibilities for exchanges between specialized arable and livestock farms. Bos and Van de Ven (1999) describe these "mixed farming systems at regional level" as providing the economic benefits of specialization at farm level and the environmental benefits of integrated cropping and livestock systems at regional level. This second definition enables the consideration of reduced transportation and energy costs as well as uneven nutrient distribution on a regional scale as a consequence of imported inputs. Figure 11 summarizes the two views of mixed farms. These exchanges of slurry, cereals or straws are aimed at increasing nutrient cycle efficiency as well as decreasing energy and inputs such as concentrates and fertilizers (CANTOGETHER, 2011).

Figure 21: Two visions of mixed farms in the CANTOGETHER project



3. RESULTS

3.1. From objectives to indicators

Setting objectives is a prerequisite for the development of indicators. It is the first step to define clearly the reason for developing indicators and our expectation. In table 10, objectives are borrowed from general goals of CANTOGETHER. These objectives are declined in sub-objectives, mostly mentioned explicitly in the proposal, and then in criteria. To define criteria, it is necessary to take into account two perspectives: on the one hand it is faster and cheaper to make use of already existing and available data; and on the other hand, it is important to make sure the important objectives of the project are properly expressed and it might be necessary to collect new data. The budget and time constraints of the project compel to make predominantly use of existing information and cautious selection of information to be collected.

Many criteria originate from the IDERICA (Girardin et al., 2004) or DIALECT methods (Solagro, 2011) which are already well established. A few criteria could be part of several sub-objectives but I chose to cluster them according to their preferable objective from my understanding of CANTOGETHER. The first two objectives to reduce dependency on external inputs and to ensure high resource use efficiency are very transversal and involve economic, environmental and social considerations. They are called here agronomic components and refer to systemic criterions.

Table 10: Declination of the objectives of CANTOGETHER into a set of criteria from the three pillars of sustainability.

Major objectives	Sub-objectives	Criterions
Reduce dependency on external inputs	Reduce the use of non-renewable energy	Quantity of mineral fertilizers
		Quantity of pesticides
		Dependency on energy inputs
	Increase self-sufficiency	Importance of home-grown stuffs
		Forage autonomy
		Concentrate autonomy
		Presence of legume
		Renewable energy production from biomass
	Decrease water use	Irrigation
Ensure a high resource use efficiency	Decrease leaching	Importance of catch crops
		N losses to ground water
	Decrease GHG	Manure storage facilities
		CO_2 emissions
		CH_4 emissions
		NH_3 emissions
		N_2O emissions
	Make an optimal use of energy, carbon and nutrients flows by rural communities	Nutrient balance
		Production efficiency
		Fertilization practices
		Local purchase of animal feed
	Increase Soil Organic Matter	OM Balance
Acceptable environmental performances	Increase biodiversity	Importance of permanent grassland.
		Ecological focus area
	Provide a good landscape quality	Crop diversity
		Cleanliness and building features
	Good soil cover management	Sensibility to erosion
Acceptable economic performances	Improve production efficiency	Increase products brute margin
		Reduce manure exportation
		Total production efficiency
		High value added outlets
	Independence to subsidies	Capacity for self-financing
	Economic viability	Labor remuneration
		Finance dependency
		Financial autonomy

Legend	(purple)	Agronomic components	(red)	Economic components
	(green)	Environmental components	(yellow)	Social component

Indicators originate from the IDERICA and DIALECT methods when they fit the criteria. This list of indicators presented in table 11 enables to understand CANTOGETHER goals and possible ways they can be assessed. They are aimed at better understanding possibilities to compare farming systems from different perspectives. From this list, I selected a set of indicators that is tested on the two case studies to compare mixed and specialized farming systems.

Table 11: Declination of criterions in a set of indicators at farm level

Criteria	Indicators	Source Indicator
Quantity of mineral fertilizers	Fertilizer (€) / Surface cropped (ha)	FADN[25]
Quantity of pesticides	TFI (Treatment Frequency Index) = sum of treatments used (kg) / standard approved dosages (kg/ha)	Ministere de l'agriculture, de l'agroalimentaire et de la foret, 2012
Dependency on energy inputs	Energy (€) / UAA (ha)	Girardin et al., 2004[26]
	Energy (€) / Euro of output (€)	FADN
	Equivalent oil (l) / UAA (ha)	Solagro, 2011[27]
Importance of home-grown stuffs	Proportion of home-grown stuff in the specific costs of farms (%)	Adapted from FADN
Forage autonomy	On-farm produced forages (t DM)/Total forage consumption (t DM)	Solagro, 2011
	Livestock Unit per hectare	Girardin et al., 2004
Concentrate autonomy	On farm-produced concentrates (t DM)/Total consumption of concentrates	Solagro, 2011
Presence of legume	Leguminous crops (ha) / UAA (ha)	Solagro, 2011
Renewable energy production from biomass	Production of renewable energy in GJ. $ha^{-1}.yr^{-1}$	Eckert et al., 2000
Irrigation	Water utilized m^3/ha UAA/year	Solagro, 2011
Importance of catch crops	Hectare of catch crops per hectare of UAA	
N losses to ground water	Residual N at harvest	Schröder et al., 2004
Manure storage facilities	Storage capacity (m^3)	Solagro, 2011
CO_2 emissions	E_{CO2} (in t)	OCDE, 2001
CH_4 emissions	$E_{CO2eq} = 21\ E_{CH4}$ (in t)	OCDE, 2001
NH_3 emissions	NH3-N/ha (kg)	Bockstaller et al, 2007[28]
N_2O emissions	$E_{CO2eq} = 310\ E_{N2O}$ (in t)	OCDE, 2001
Nutrient balance	Farm gate nitrogen balance (kg/farm/year)	Dairyman, 2011
	Farm gate phosphorus balance (kg/farm/year)	Dairyman, 2011
Production efficiency	Total outputs (€) / Total inputs (€) * 100	FADN
	(Tot output (€) - tot input (€))/ tot. Output (€)	Girardin et al., 2004
Nutrients imports	Nitrogen imported (kg N/ha UAA/year)	Solagro, 2011
	Phosphorus imported (kg P/ ha UAA/year)	Solagro, 2011

[25] All variables from the FADN database used in this table are explained in annex 13.
[26] The internal publication (Girardin et al., 2004) refers to the IDERICA method.
[27] Solagro created the DIALECT method.
[28] This reference refers to the INDIGO method, based on agri-environmental indicators.

Local purchase of animal feed	Forage and concentrates bought within 50km (€) / Total purchase of forage and concentrates (€)	Solagro, 2011
OM Maintenance	Area receiving organic matter (ha)/UAA (ha)	Solagro, 2011
Importance of permanent grassland	Permanent grassland (ha)/UAA (ha)	Girardin et al., 2004 / Solagro, 2011
Ecological focus area	AEM (€)/UAA (ha)	Girardin et al., 2004
	Sum of total ecological structures (ha)/UAA (ha)	Solagro, 2011
	Area of biological interests (Natura 2000 etc.) (ha)	Solagro, 2011
Crop diversity	Number of annual crops	Solagro, 2011
	Number of perennial crops	Solagro, 2011
Cleanliness and building features	Description	Guillaumin et al., 2007
Sensibility to erosion	Bare soils the 31th of December (ha)/UAA (ha)	Solagro, 2011
Increase product brut margin	Revenue (€) / ha of production	
	Revenue (€) / kg or t of product	
Reduce manure exportation	Exportation of manure in equivalent N (kg/farm/year)	Adapted for CANTOGETHER
	Exportation of manure in equivalent P (kg/farm/year)	Adapted for CANTOGETHER
Total production efficiency	Total intermediate consumption (€)/ Total output (€)	FADN
Capacity for self-financing	Subsidies (€) / Gross farm income (€) * 100	Girardin et al., 2004
Labor remuneration	Labor remuneration of family members (€/FWU)	Girardin et al., 2004 / FADN
	Labor remuneration of farm workers (€/AWU)	FADN
Finance dependency	Total liability (€) / net worth (€)	Adapted from FADN
Financial autonomy	Total liability (€) / Gross farm income (€)	Girardin et al., 2004

Legend		Agronomic component		Economic component
Information missing		Environmental component		Social component

3.2. Setting reference values

Table 12 presents the set of indicators tested to evaluate and compare mixed farming systems and specialized farming systems. The color code remains the same as for the previous tables.

Table 12: Selection of indicators and their associated data source and reference value

Indicator	Data source	Reference value	Description threshold value
Energy (€) / UAA (ha)	FADN	776.2 €/ha 108 €/ha	Average all farm type except horticulture, FADN 2009
Energy (€)/ Total output (€)	FADN	0.046 €/€ 0.058 €/€	Average all farm type except horticulture, FADN 2009
Home-grown stuff (€) / Farms' specific costs (€)	FADN	2.1% 2.9%	Average of all farm types, FADN 2009
Stocking density (LU/ha)	Local		
Farm gate N balance (kg)	Local		
Farm gate P balance (kg)	Local		
(Total output (€) –total inputs (€)) / Total output (€)	FADN	3.1% -13.6%	Average of all farm types, FADN 2009
N imported (kg/farm/year)	Local		
P imported (kg/farm/year)	Local		
Permanent grassland (ha) / UAA (ha)	Local		
Agro Ecological Measures (€) / UAA in (ha)	FADN	15.6 €/ha UAA 13.3 €/ha UAA	Average of all farm types except for horticulture and specialized sheep and goats, FADN 2009
N exported (kg N/farm/year)	Local		
P exported (kg P/farm/year)	Local		
Total subsidies (€)/ Gross farm income (€)	FADN	16.2% 52.4%	Average of all farm types, FADN 2009
Farm net income (€) / FWU	FADN	12,400 €/FWU 7145 €/FWU	Average of all farm types, FADN 2009
Total liability (€) / Gross farm income (€)	FADN	4.76 2.26	Average of all farm types, FADN 2009

Legend			
	Agronomic components (purple)	Economic components (pink)	The Netherlands (orange)
No fixed reference value (grey)	Environmental components (green)	Social components (light yellow)	Aquitaine (blue)

3.3. Descriptions of typical farms

In this section, typical farms are defined according to expert knowledge for the municipality of Winterswijk and the Ribéracois. Hein Korevaar is the expert who helped me to define farms in Winterswijk and Benjamin Nowak helped me for the Ribéracois, based on the first results of his PhD thesis[29]. Data present in both cases are different and I compiled a minimum set of information needed to carry out the analysis. Tables 13 and 14 summarize the structure of typical farms respectively in Winterswijk and in the Ribéracois.

Table 13: Typical dairy, arable and mixed farms of the Winterswijk municipality based on expert judgment

Prodution details	Units	Typical dairy farm	Typical arable farm	Typical mixed farm
Total UAA	ha	57	80	80
Grassland	ha	40		30
Of which permanent grassland	ha	32		24
Forage crops (mostly maize)	ha	17	10	15
Grains	ha		30	18
Potatoes	ha		30	15
Sugar beats	ha		5	2
Other	ha		5	
Livestock				
Dairy cows	n	90		65
Young stock	n	66		42
Pigs	n			400
Stocking density	LU/ha	2		2
Housing		cubicle house		cubicle house
Milk production				
Per hectare	kg/ha	12,000		
Per cow	kg/yr	8,075		8,075
Fat	%	4.41		4.41
Protein	%	3.48		3.48

Source: Korevaar, personal communication 2012

[29] Benjamin Nowak is doing a PhD about nutrient cycling in organic agriculture at INRA-Bordeaux and the results of some case studies are used in the CANTOGETHER project. The typical farms designed in the Ribéracois are based on his inquiry of 17 organic farms.

Table 14: Typical organic goat, arable and mixed farms of the Ribéracois based on expert judgment

	Units	Typical goat farm	Typical arable farm	Typical mixed farm
PRODUCTION DETAILS				
Total UAA	ha	30	53	57
Grassland	ha	25	10	24
of which permanent grassland		25	10	10
Forage crops (mostly maize)	ha	5	11.5	10
Arable crops	ha	0	31.5	23
Livestock				
Goats	n	100		160
Young stock	n	15		25
Stocking density	LU/ha	0.4		0.3
Manure produced	t/year/farm	220		350
Milk production				
per goat	kg/yr	650		900
RATION				
Importation				
Concentrates (co-products)	kg/goat/yr	75		150
Cereals	kg/goat/yr	175		
Self-production				
Forage	T MS/yr	35		70
Cereals	T MS/yr	0		45
FARM GATE BALANCE[30]				
Nitrogen	kg/ha	50	55	47
Phosphorus (P2O5)	kg/ha	4.3	3	4.3
FERTILIZATION				
Fertilizers				
Manure export	t/farm/year	0	0	0
Manure import	t/farm/year	0	0	0
Organic fertilizer		0		
N	kg/ha		125	0
P2O5	kg/ha		32	0

Source: Nowak, 2012

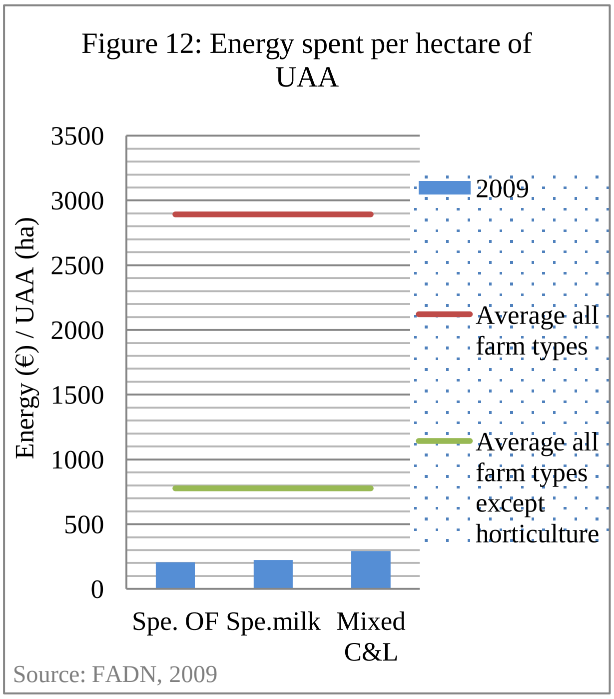
[30] Farm gate balances are calculated according to Benjamin Nowak's doctoral thesis. He defined his own formulas to calculate outputs and inputs in terms of equivalent phosphorus and nitrogen and considers a broad range of activities such as nitrogen fixation, crop residues left on-farm etc. They are the result of on-farm data collection.

3.4. Comparison between specialized and mixed farms in Winterswijk

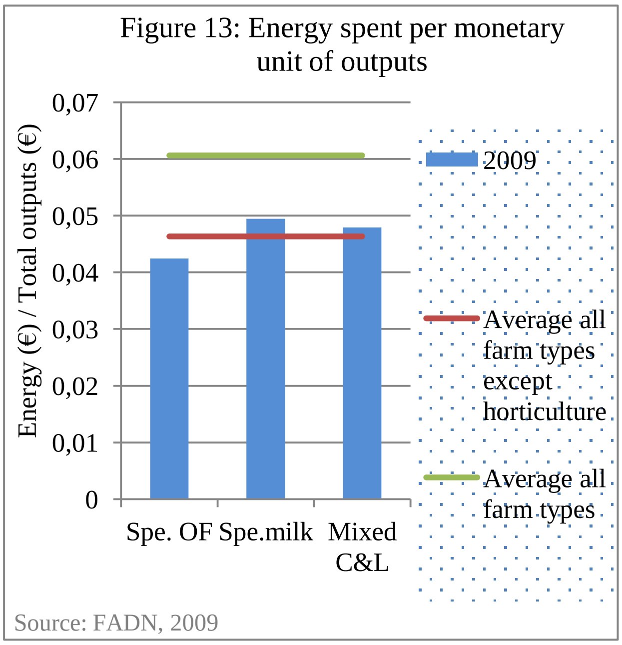
3.4.1. Comparison based on FADN database: The Netherlands

The first part of the comparison focuses on data from FADN to explore global trends and patterns between three farm types in the Netherlands. Because the sample of COP farms is not large enough to be represented in the database, I use data from the category "Specialized other field crops". Thus, the following graphs describe farms from the FADN region "The Netherlands" with the following farm types abbreviations: "Spe. OF" stands for Specialized other field crops; "Spe. Milk" stands for Specialized dairy and "Mixed C&L" stands for mixed crop and livestock. Finally, headings of adapted colors remind major objective, sub-objective and criterion in which the indicator belongs.

Objective	Sub-objective	Criterion
Reduce dependency on external inputs	Reduce the use of non-renewable energy	Dependency on Energy inputs



The first indicator shown in figure 12 exhibits the dependency of farms on energy inputs in Euros per hectare. It does not give indication about the efficiency of the production system but rather exhibits the amount of oil, gas and electricity consumed in Euros per hectare of UAA and per farm type in 2009. Ranging between 200 and 400 €/ha, the dependency of these systems on oil is relatively low in comparison to all other farm types and do not show significant difference. The two different averages, with and without horticulture farms, allow to correct the substantial bias when considering horticultural productions, which make considerable consumption of gas to heat greenhouses (26,000€/ha in average). Finally, the price of energy per hectare is biased due to possible differences in the intensity of systems and do not show the dependency of production on energy inputs.



It appears clearly in figure 13 that there is almost no difference between farm types regarding the energy expenses per monetary unit of output. Around 5% of total outputs is spent on energy inputs, that is 5 cents for each euro of product sold. It corresponds to the average amount spent by all farm types in the Netherlands. We notice a slightly smaller use of energy for specialized field crops. However, despite the low significant differences between dairy and mixed farms, energy use is different. Whereas milking and cooling milk are the most important posts in a dairy farm, oil spent in tractors might be the important post in mixed farms. With respect to figure 12, the average is pushed up by horticultural production which spends 22 cents of energy per euro output. It is a very energy intensive production, per hectare as well as per monetary value of products.

Objective	Sub-objective	Criterion
Reduce dependency on external inputs	Increase self-sufficiency	Importance of home grown stuff

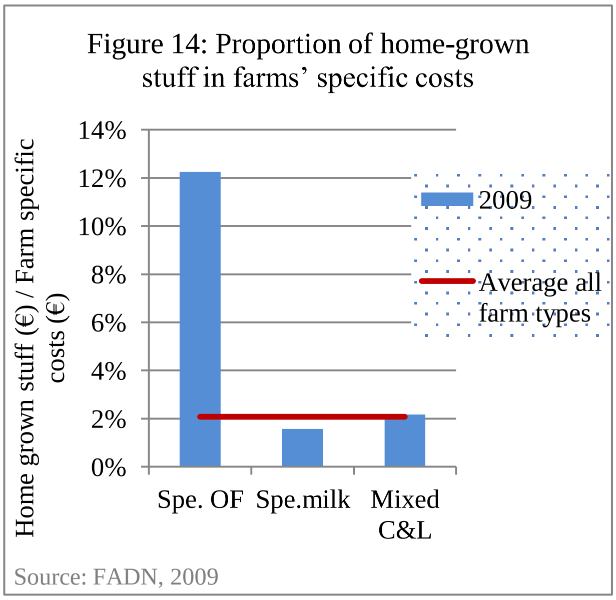


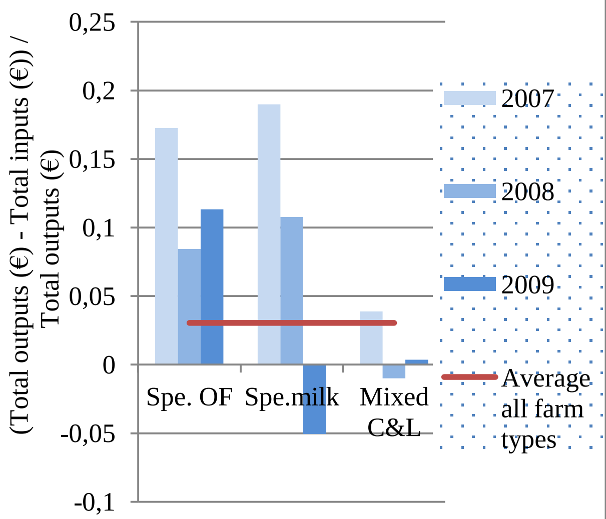
Figure 14 shows the value of home-grown materials[31], be it seeds for planting or feed for livestock, in proportion of specific costs which include all costs involved directly in the production process (labor costs not being included). Specialized field crops reach a particularly high value of 12% of self-produced material for production. This value could be "too" high if it decreased significantly the sold production of farms. This includes for the largest part seeds and seedlings for potatoes and other field crops such as onions or carrots. Besides, mixed farms and milk farms are around the average and exchanges of materials within the farm are common practices. For instance, cereals in mixed farms used to feed cattle and milk in dairy farms used to feed young stock or some pigs. It is interesting to note that roughage is not taken into account in this figure and home-grown stuff refers to end products reused within the farm. However, these exchanges remain marginal and represent only 2% of total production costs. It shows a quite

[31] Home grown material refers in the FADN to end-products reused within the farm.

important marge of progression to increase the self-sufficiency of farms. Globally, the figures for other specialized productions show an overall poor internal flow of materials almost all below 2%.

Objective	Sub-objective	Criterion
Ensure a high resource use efficiency	Make an optimal use of energy, carbon and nutrients flows by rural communities	Production efficiency

Figure 15: Production efficiency

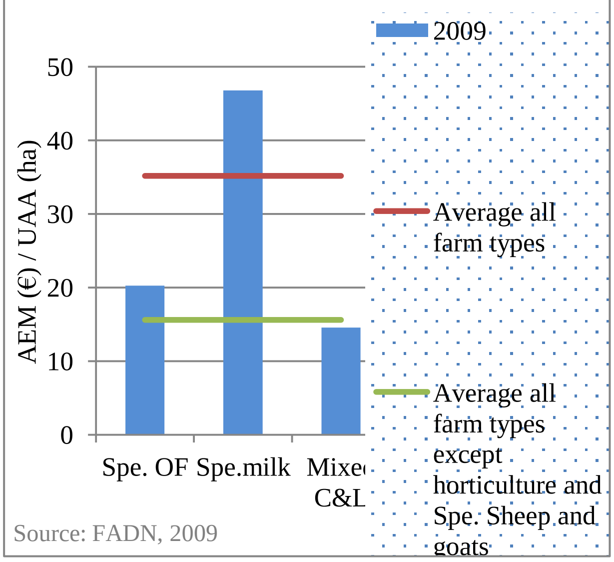


Source: FADN, 2007, 2008, 2009

Figure 15 expresses the production efficiency by comparing the added value produced on farm with the total amount of output. Important and unequal variations can be perceived between years and farm types. The year 2007 shows high prices for all farm types. While 2008 shows a major recession for all farm types, 2009 present contrasted outcomes. Mixed and field crops farms are improving their production efficiency whereas dairy farms reflect an even stronger recession due to high prices for feed and concentrates and low prices for production. Globally, mixed farms seem to have the biggest resilience and dairy farms the lowest stability. However, over the three years studied, mixed farms show an overall poor efficiency, often below average, while specialized field crops show very high production efficiency. In general, all farm types have a positive production efficiency which is remarkable (it is possible to see the point from another perspective and in fact, one can point out that most European countries have low or negative production efficiency). This indicator varies importantly from one year to another and is strongly influenced by investments of past years, subsidies perceived and year's income.

Objective	Sub-objective	Criterion
Acceptable environmental performances	Increase biodiversity	Ecological focus areas

Figure 16: Agri-environmental subsidies

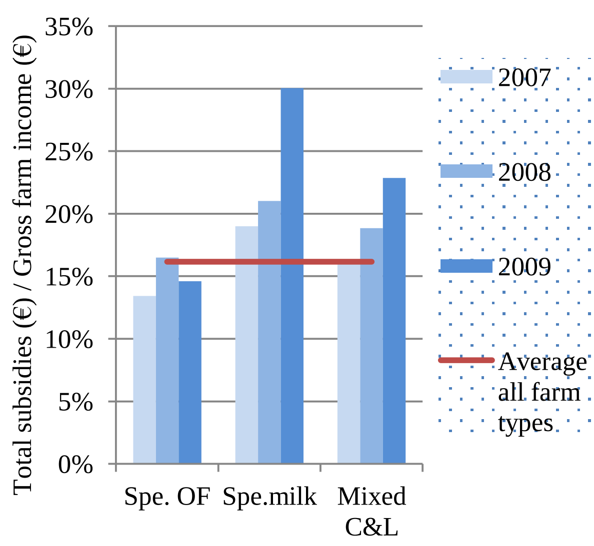


Source: FADN, 2009

Figure 16 shows the amount of agri-environmental (AE) subsidies earned per hectare of UAA. Because specialized horticulture and specialized sheep and goats farms earn respectively 146 and 100 €/ha of AE subsidies, two averages are drawn on the graph. While dairy farms receive important subsidies because of significant surfaces kept in permanent grassland, mixed farms do not reach the adjusted average. Permanent grasslands provide nesting areas for meadow birds which are of major importance in the Netherlands. On the other hand, mixed farms include grassland in their rotation with potatoes, cereals or silage crops. Thus, most grassland is ploughed from time to time and inappropriate for meadow birds to nest. In the between, other field crops farms earn about 20€/ha of UAA mostly for maintaining buffer zones, field margin and hedgerows.

Objective	Sub-objective	Criterion
Acceptable economic performances	Independence to subsidies	Capacity for self-financing

Figure 17: Share of subsidies in the gross farm income

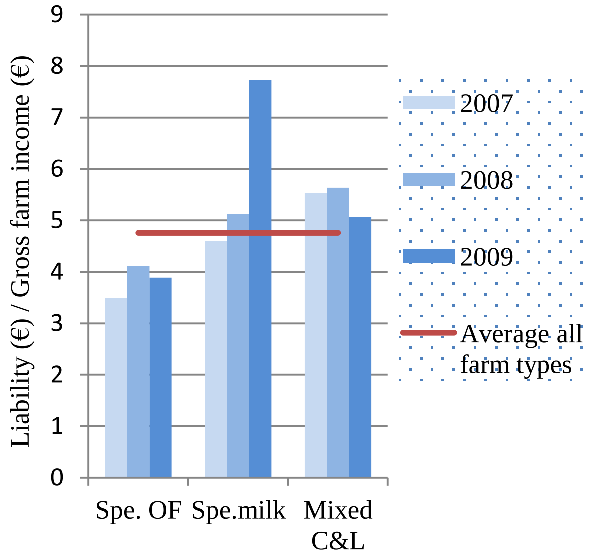


Source: FADN, 2007, 2008, 2009

The indicator share of subsidies in the gross farm income expressed in table 17 reflects the capacity of farmers to earn their own living and include the total amount of subsidies perceived from the first and second pillar of the CAP. The higher the percentage, the more dependants the farm is. Also, depending on the value of the gross farm income, the amount of money self-earned will vary accordingly. Therefore it is advisable to study this indicator over several years to efface the income variability between years. Farmers' capacity to earn their own income seems to decrease steadily. Dairy farms show the most brutal increase in the proportion of subsidies in the gross income between 2008 and 2009. An important decrease of their income carries this trend. They are the farm type that rely the most on subsidies, up to 30% of their gross income. On the other hand, field crops farms are the most independent farms and in 2009, only 13% of the gross farm income comes from subsidies. Overall, farms tend to become increasingly dependent on subsidies but the graph does not show this tendency either because incomes are decreasing, subsidies are increasing or both of them. It is most likely income shrinking.

Objective	Sub-objective	Criterion
Acceptable economic performances	Economic viability	Financial autonomy

Figure 18: Capacity to honour debts

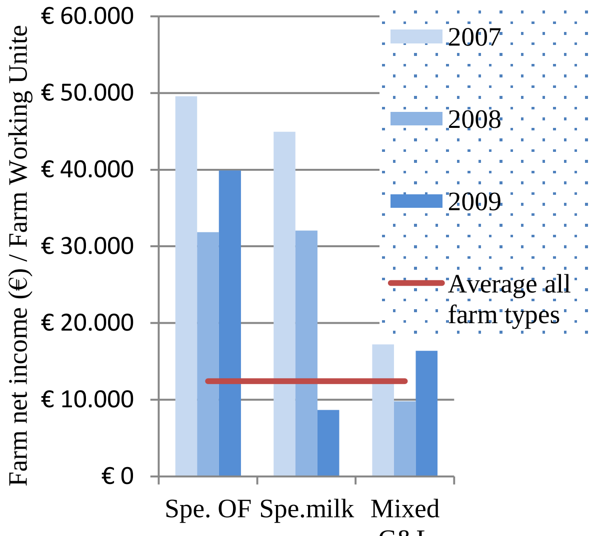


Source: FADN, 2007, 2008, 2009

In order to indicate the financial autonomy of farms, figure 18 shows their liability, including short, medium and long term loans, in comparison to their gross income. It indicates to what extent farming activity is dependent on bank loans. Dairy farms exhibit a tremendous dependency on loans for production due to high investments in 2009. They owe up to 7.7 times the value they can produce per year. Mixed farms are just above the average but still depend heavily on borrowed money. Their liability remains 5 times higher than their gross income. To put it more clearly, for each euro earned with the production (subsidies being part of the production) €5 are borrowed to a bank. If we consider previous results about subsidies for a dairy farmer in 2009, each euro of gross income is composed of 30 cents from the government and 70 cents that he/she produced by borrowing €7.7 to a bank!

Objective	Sub-objective	Criterion
Acceptable economic performances	Economic viability	Labor remuneration

Figure 19: Labour remuneration per family working unit



Source: FADN, 2007, 2008, 2009

The labor remuneration of household seems to be quite irregular and many factors will influence the final income of a farmer and his/her family. In figure 19, a significant shrinkage is observed in 2009 for dairy farmers' income, dropping far below the national average of 12,400€/FWU. It has a strong influence on the farm production efficiency (Cf. figure 14). On the other hand, earning of mixed and field crops farms has increased. In 2009, a "mixed farmer" earned €16,300 that is 1,360€/month, far below the income of a field crops farmer earning 3,330€/month.

3.4.2. Comparison based on local data: Winterswijk

Objective	Sub-objective	Criterion
Acceptable economic performances	Improve production efficiency	Reduce manure exportation

Table 15 shows the amount of manure exported out of typical farms in the municipality of Winterswijk (Cf. calculation details in annex 14). This indicator is clustered as an economic parameter since all export of manure is charged to farmers. Thus, economical constraint of manure export is the primary concern of farmers, before environmental harm. However, in the CANTOGETHER project, environmental concerns are essential and the objective is to keep manure as much as possible in the surrounding area.

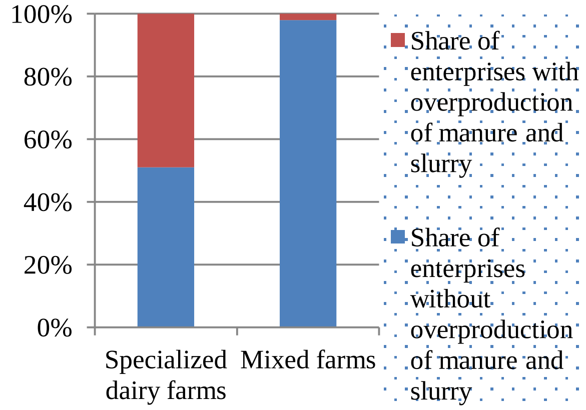
Table 15: Manure exported out of typical farms expressed in equivalent nitrogen and phosphorus

	Typical OF farm	Typical milk farm	Typical mixed farm
Nitrogen (kg N/farm/year)	0	522	0
Phosphorus (kg P/farm/year)	0	190	0

Source: Korevaar, personal communication 2012

The 522 kg of nitrogen exported per typical milk farm and per year as well as 190 kg of P2O5 per farm and per year correspond to 127 tons of manure exported if we consider that one ton of manure contains 4.1 kg of nitrogen and 1.5 kg of P_2O_5 (Kennisakker, 2012). In the case of arable farms and mixed farms, they use more nutrients than the quantity they "produce" on-farm as table 16 shows.

Figure 20: Manure overproduction* in the province of Gelderland



Source: CBS, 2009 *Following Dutch derogation

Figure 20 shows the proportion of mixed and dairy farms having slurry and manure surpluses. The surpluses are calculated on the basis of their own land considered as fully fertilized with manure. In the Netherlands, under certain conditions, farmers have a derogation to apply 250 kg of nitrogen of animal manure (cattle, sheep, goats and horses) per hectare of grassland or fodder crop when the farm has at least 70% of the UAA in grassland. Overall, 50% of dairy farms have manure over production in Gelderland. Most of the time, the manure is sold to a “manure collector company” for transportation to arable farms of other provinces. Mixed farms on the contrary do not have 70% of their UAA in permanent grassland and therefore apply the regulatory amount of 170kg of nitrogen per hectare. However, very few mixed farms have manure surpluses and all slurries are spread on fields.

Objective	Sub-objective	Criterion
Ensure a high resource use efficiency	Make an optimal use of energy, carbon and nutrients flows by rural communities	Nutrients imports

Nutrient import indicators, unlike nutrient export indicators, are clustered as agronomical parameter because of the many implications they have for farmers and the surrounding community. For instance, it closes nutrient cycles, decreases imports of mineral fertilizers, increases soil organic matter and therefore promotes soil biodiversity etc. These importations are studied into greater details in the CANTOGETHER project (WP4). The idea is to source these imports in the surrounding area as much as possible. Table 16 shows the potential amount of nutrients imported in typical farms.

Table 16: Potential amount of N and P_2O_5 imported as animal manure in typical farms for fertilization purposes

	Typical arable farm	Typical milk farm	Typical mixed farm
Nitrogen (kg N/farm/year)	13,600	0	4,237
Phosphorus (kg P_2O_5/farm/year)	6,400	0	3,405

Source: Korevaar, personal communication 2012

A more in-depth study would probably show that an important part of imported nitrogen and phosphorus is under inorganic forms. Thus, if we consider tables 15 and 16, it shows the theoretical potential to shift a part or the totality of fertilizer applications from inorganic forms to an organic form from local manure surpluses. In practice, it is a challenge to foster such exchanges and

CANTOGETHER will take a closer look at those possibilities by organising workshops and meetings with relevant stakeholders.

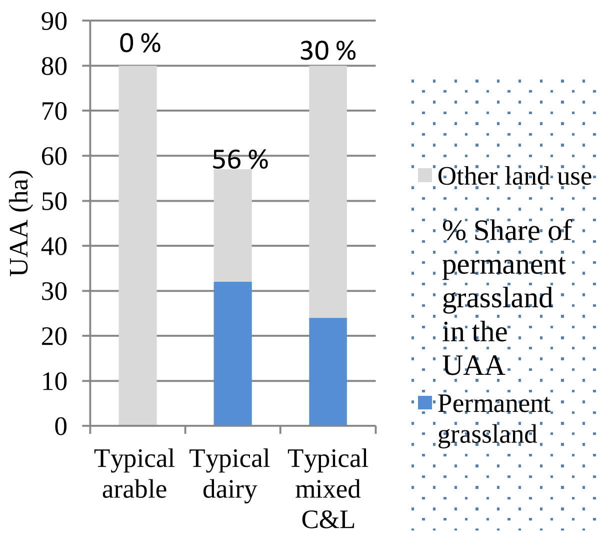
Very interesting on-going experiments in the Netherlands concerning slurry separation could prove to be of major importance to set up in practice these exchanges of materials. It provides a solid phase rich in phosphorus and a liquid phase rich in nitrogen with a determined phosphorus and nitrogen content. It is very interesting for farmers who would like to substitute mineral fertilizer with organic fertilizers while keeping good record of their fertilization practices.

Objective	Sub-objective	Criterion
Ensure a high resource use efficiency	Make an optimal use of energy, carbon and nutrients flows by rural communities	Nutrient balance

Data missing

Objective	Sub-objective	Criterion
Acceptable environmental performances	Increase biodiversity	Importance of permanent grassland

Figure 21: Proportion of grassland in farms' UAA



Source: Korevaar, personal communication 2012

In figure 21, the proportion of grassland indicates the impact of farms on biodiversity. Although there is no direct relationship between grassland and natural biodiversity, we assume that it is a good prerequisite to keep diversity within a farm. This figure shows mainly two results; the absolute amount of grassland and its relative proportion in typical farms of Winterswijk. Mixed farms show a smaller proportion of permanent grassland because part of the total surface in grassland is included in the rotation and ploughed cyclically. On the other hand, dairy farms tend to keep a larger proportion (56%) of permanent grassland to feed the cattle. However, dairy farms still have 44% of their UAA devoted to other land use, among which important surfaces for fodder crops and temporary grassland. Finally, arable farms do not keep any surface in permanent grasslands and all fields are included in a crop rotation. A common practice for arable farmers, and particularly potatoes growers, is to rent and plough grassland of dairy farms to lengthen their rotation.

Objective	Sub-objective	Criterion
Reduce dependency on external inputs	Increase self-sufficiency	Forage autonomy

The indicator of livestock density expressed in livestock unit (LU) per hectare is used here to assess the extent to which a farmer is autonomous in forage supply. Forage autonomy has a range of implications for farmers' practices and the more farmers rely on pasture for their production the less they rely on brought-in feed stuff. Consequently the lower the inputs, the lower the farm dependency on oil industries and imported feed. In the area of Winterswijk, the high productivity of grassland, around12 tons per hectare, allows farmers to entirely cover their needs in grass for the year with 2 LU/ha. It is important to mention that an important part of their ration is composed of silage and concentrates which reduces significantly the need of grass.

Table 17: livestock density in typical dairy farm and typical mixed farm of Winterswijk

	Specialized dairy	Mixed farms
LU/ha	2	2

Source: Korevaar, personal communication 2012

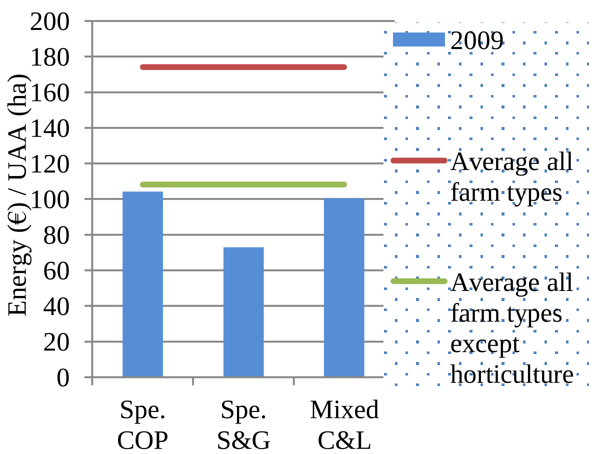
3.5. Comparison between specialized and mixed farms in the Ribéracois

3.5.1. Comparison based on FADN database: Aquitaine

For the second case study, we are going to study different farm types, more relevant for the Ribéracois. The following abbreviations are used: "Spe. COP" stands for Specialized Cereals and Oil and Protein crops, "Spe. S&G" stands for Specialized Sheep and Goats and "Mixed C&L" stands for Mixed Crops and Livestock. In this section all graphs display data from the "Aquitaine" region in 2009 except when specified differently.

Objective	Sub-objective	Criterion
Reduce dependency on external inputs	Reduce the use of non-renewable energy	Dependency on Energy inputs

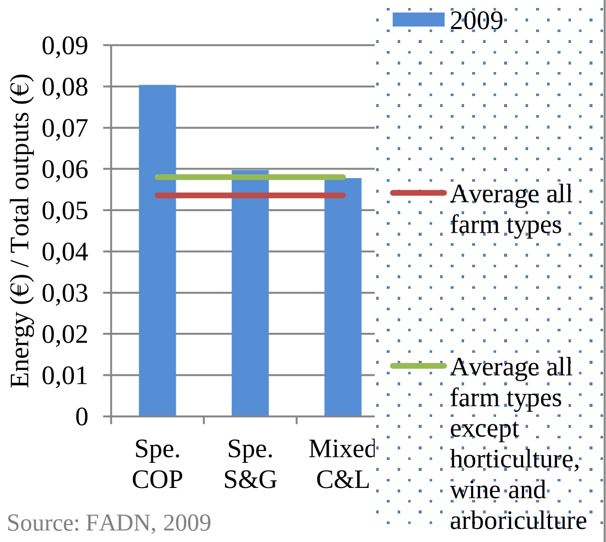
Figure 22: Energy spent per hectare of UAA



Source: FADN, 2009

Figure 22 shows a tendency from the three production systems to have energy expenses per hectare below average, ranging from 65 to 100 €/ha. While the red average includes all farm types, the green average does not consider horticulture (data are missing), wine yards and orchards with a very intensive production per hectare. The partial average is much lower and more robust to consider when comparing crop and animal systems. There is a tendency of spe. S&G to perform better than mixed C&L and specialized COP which might be due to the use of extensive natural grassland. Concerning specialized COP and mixed farms, it is difficult to make further conclusions with this figure except that they are both below the adapted average.

Figure 23: Energy spent per monetary unit of output



Comparing the money spent on energy with output value of products gives relatively little differences between COP farms and the two other groups. We notice a 2 cents difference per euro of output. According to figure 23, mixed and Spe. S&G farms are similar and show an average dependency on emery inputs. We notice also that both averages are only different of half a cent which means that wine and horticulture spend the same proportion of money on energy per euro of output than other systems (data for arboriculture are missing). This is a very contrasting result with Dutch horticulture which is far more energy intensive. Dutch agriculture is globally more efficient.

Objective	Sub-objective	Criterion
Reduce dependency on external inputs	Increase self-sufficiency	Importance of home grown stuff

Figure 24: Proportion of home-grown stuff in farms' specific costs

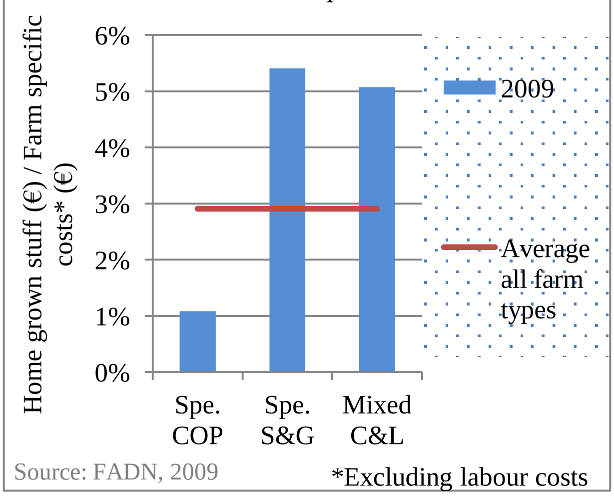


Figure 24 displays the proportion of home grown products which are reinvested within the farm. This indicator gives an idea on the internal fluxes of products within a farm. More particularly it shows the intention of farmers to reuse their own end products and increase the added value produced on-farm. Here, specialized S&G and mixed farms reuse up to 5.5% of their productions within the farm which is far above the average of 3%. It can be explained partly by the important flows of products between crops and animal production in a mixed farm (manure handling is not included) but also among animals, for instance milk for young animals in the S&G farm. On the other hand, specialized COP buy seeds, fertilizers, and other treatments every year and sell the totality of their production away. The one percent indicated in the graph refers to plants and seeds kept on farm. Overall, all systems have a tremendous need of external inputs of all kinds which represents between 95 and 99% of their production costs (energy, seeds, feed for livestock etc.).

Objective	Sub-objective	Criterion
Ensure a high resource use efficiency	Make an optimal use of energy, carbon and nutrients flows by rural communities	Production efficiency

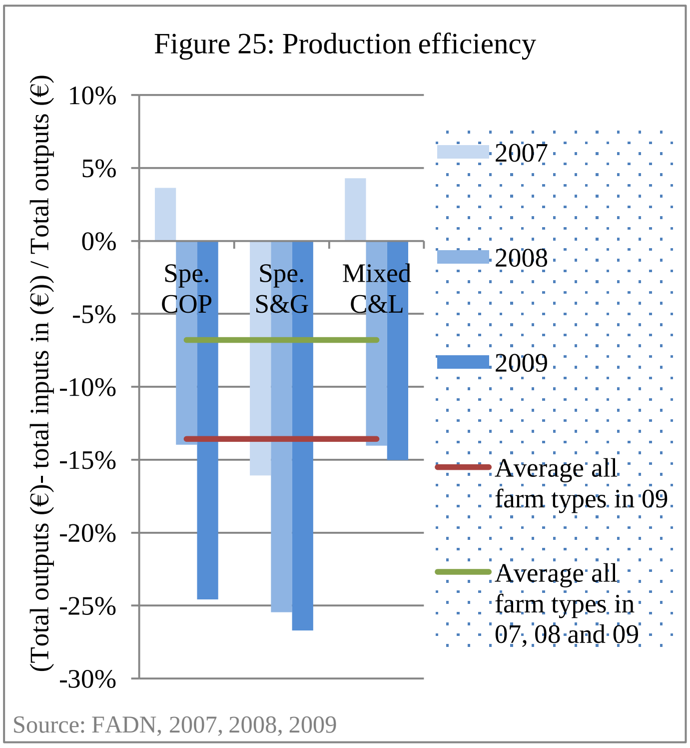
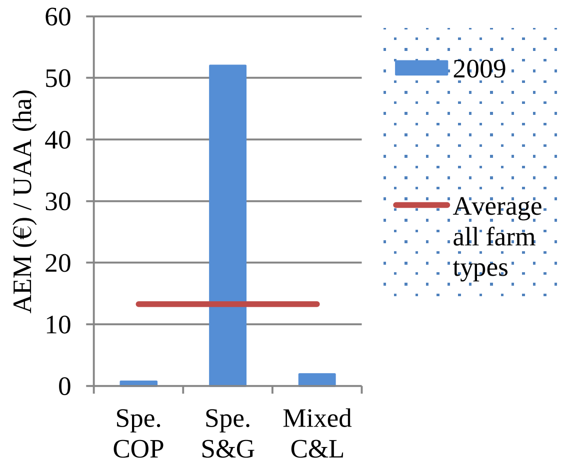


Figure 25 shows that the production efficiency is below zero for all production systems and for 2008 and 2009. Moreover, the efficiency is below the regional average in all three production systems in 2009. Finally, the average for all production systems and over three years is negative. So not only these systems have a negative efficiency, but they are less efficient compared to other systems (showed by the green average), especially for COP and specialized S&G. While mixed systems present the best results and reach almost 5% in 2007, specialized S&G are showed to be by far the less efficient system. One very important factor that determines production efficiency is the reliance on subsidies. Extensive S&G systems benefit of important subsidies. It is also possible but less probable that these systems make a suboptimal use of natural resources in their agroecosystems and/or that these three years are simply a bad conjuncture.

Objective	Sub-objective	Criterion
Acceptable environmental performances	Increase biodiversity	Ecological focus areas

Figure 26: Agri-environmental payments per hectare

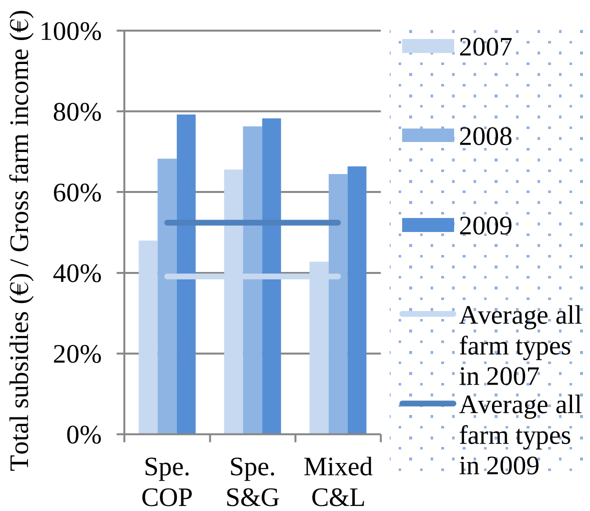


Source: FADN, 2009

Average AE payments reach 13€/ha of UAA but farming systems are not equally beneficiary. The amount of subsidies perceived by specialized S&G is far above the average and the two other production systems as shown by figure 26. This is directly the result of extensive surfaces of grassland and pastures, having an important place in AE payments for they contain large proportion of biodiversity. On the other extreme, it is very constraining for specialized COP to set up buffer zones, maintain fallow land, grasslands and hedgerows. Mixed farms, depending on their activities do not have the same eligibility for AEM. In the Ribéracois, mixed farms often are dairy goat farms with pastures and silage maize.

Objective	Sub-objective	Criterion
Acceptable economic performances	Independence to subsidies	Capacity for self-financing

Figure 27: Share of subsidies in the gross farm income

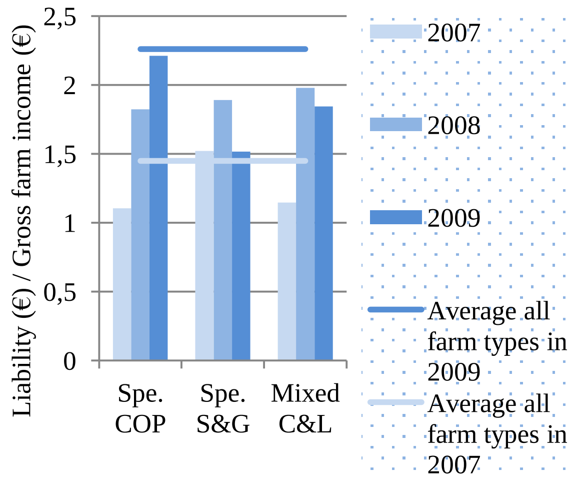


Source: FADN, 2007, 2008, 2009

Figure 27 shows a clear tendency for the proportion of subsidies in the gross farm income to increase markedly from 2007 to 2009 for the three farm types. This trend is led at first instance by a decrease in income. Overall, mixed systems show the best performance compared to specialized S&G and COP farms even though they still rely heavily on subsidies (from 40% in 2007 up to 65% in 2009). Thus, these three systems show above average dependency on subsidies and rely substantially on governmental help to earn their revenue. Also, the higher the dependency, the less significant the difference between systems. For instance in 2007, the comparison between mixed and specialized S&G (respectively 43% and 66%) is larger than that of 2009 where the difference ranges from 66% to 78%. We observe a faster increase in dependency on subsidies for specialized COP than for specialized S&G or mixed farms. Overall, the average proportion of subsidies in the gross farm income for all farm types in Aquitaine has increased from 39% to 52% between 2007 and 2009 which deteriorates farmers' capacity to make up their earnings. Compared to Dutch agriculture, the difference is striking and they reach an average of 16% in 2009.

Objective	Sub-objective	Criterion
Acceptable economic performances	Economic viability	Financial autonomy

Figure 28: Capacity to honour debts

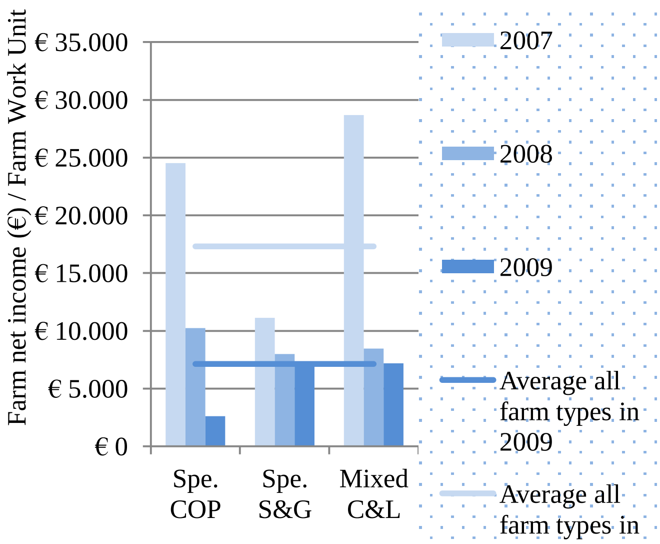


Source: FADN, 2007, 2008, 2009

Figure 28 shows the ability of farmers to cover their debts with respect to their gross farm income. The higher the ratio, the lower the financial autonomy. When the ratio increases, either farmer are loaning more money, either their gross farm incomes decrease or both at the same time. Thus, we notice a decreasing ability of farmers to pay their loans back except for specialized S&G. This trend is also influenced by punctual investments and it is difficult to forecast future trends. This data vary greatly between farms and systems. However, the average ratio for all farms in Aquitaine increases of 0.75 euro per euro of gross farm income between 2007 and 2009. Overall, these three farm types are among the more autonomous and specialized S&G are moving away below the regional average. In contrast, we will find for instance in 2009 specialized milk farms having a ratio of 4.5! Probably due to massive investments in previous years and a decreased income in 2009.

Objective	Sub-objective	Criterion
Acceptable economic performances	**Economic viability**	**Labor remuneration**

Figure 29: Labour remuneration of farm family members



Source: FADN, 2007, 2008, 2009

The rapid and substantial shrinkage of family working units' remuneration between 2007 and 2009 is striking. Figure 29 shows an important drop off in 2008 due to an unfavorable conjuncture that attain more importantly specialized COP and mixed farms. The average income per FWU in Aquitaine dropped from 17,000 €/FWU in 2007 to 7,000 €/FWU in 2009. Moreover, specialized COP and mixed farms that used to have revenue far above the average in 2007 have now barely average revenue in 2009. The situation has become catastrophic for COP farmers with a net income per family worker around 2600 €/FWU and per year. Mixed and specialized S&G farms reach the average income of €7200 in 2009 that is 600 €/month!

3.5.2. Comparison based on local data: The Ribéracois

In this section, farm types described are not representative farms or statistical entities but rather typical farms, designed by experts and adapted to the local situations. Those farms are typical of the Ribéracois and very different from those depicted in the FADN database.

Objective	Sub-objective	Criterion
Acceptable economic performances	Improve production efficiency	Reduce manure exportation

Table18 shows manure and slurry movements out of each typical farm. These movements are expressed in terms of equivalent nitrogen and phosphorus. There are no fluxes of manure out of farms which is not surprising since the study focuses on organic farms. Unlike conventional farms, organic farms tend to consider manure as a resource rather than a waste product. Additionally, the regulation for organic agriculture imposes a limited stocking density. Thus, all manure is stored and used on farm, spread on grasslands and crop fields. When a farmer exports manure, it would be interesting to know where the manure goes and a more in-depth study would reveal important information.

Table 18: Manure exported out of typical farms expressed in equivalent nitrogen and phosphorus

	Typical goat farm	Typical arable farm	Typical mixed farm
Nitrogen (kg N/farm/year)	0	0	0
Phosphorus (kg P/farm/year)	0	0	0

Source: Nowak, 2012

Objective	Sub-objective	Criterion
Ensure a high resource use efficiency	Make an optimal use of energy, carbon and nutrients flows by rural communities	Fertilization practices

As a second step, it is interesting to note farmers' fertilization practices to assess the need for nitrogen and phosphorus in an area (represented in table 19). A more careful analysis would enable to evaluate the quality of these fertilizers and their origin. Here, all stockless farms import meat flower and dry poultry manure produced in Bretagne and sold locally by the cooperative CORAB (Benjamin Nowak in interview). It is likely that most goat and mixed farms do not reach the 170 kg of nitrogen per hectare. Therefore, eventual surpluses could be spread on those farms. Although organic farm have important constraints to use solely organic materials, they can under certain condition also import manure from conventional farms. This last point might be interesting to explore further local cooperation between farmers. Another interesting example of local cooperation in the area is the use of composted materials from local green waste.

Table 19: Amount of nitrogen and phosphorus used in typical farms for fertilization purposes

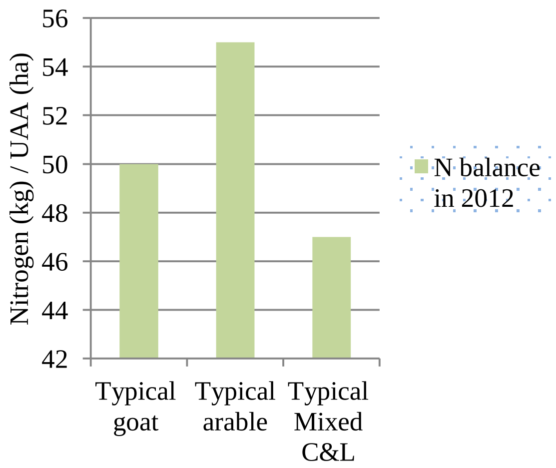
	Typical goat farm	Typical arable farm	Typical mixed farm
Nitrogen (kg N/farm)	0	6625	0
Phosphorus (kg P2O5/farm)	0	1696	0

Source: Nowak, 2012

Objective	Sub-objective	Criterion
Ensure a high resource use efficiency	Make an optimal use of energy, carbon and nutrients flows by rural communities	Nutrient balance

Nutrient balances are used to assess the efficiency of the cropping production systems, the sufficient supply of nutrients to plants but also risks for nutrient leaching, gaseous losses or the importance of nitrogen fixation. However, a farm gate nutrient balance as presented by figure 30 and 31 provides only a coarse appreciation of the general use of nutrients. We may qualify the balance of excessive, negative or balanced.

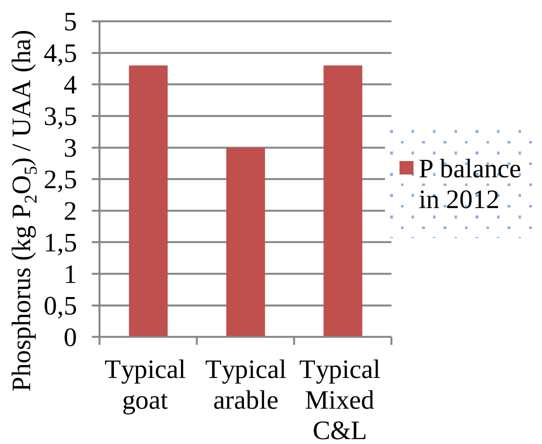
Figure 30: Farm gate nitrogen balance



Source: Nowak, 2012

The nitrogen balance is the best in mixed farms with a surplus of 47 kg/ha of UAA. Such a surplus can lead to pollution problems. When the nitrogen fertilization is excessive, there are high risks of pollution by NH3, N2O and N2 by volatilization and NO3 by leaching. When the fertilization is too low, there is a risk to lose a part of soil organic nitrogen and deplete soil reserves. Losses between 100 and 125 kg N/ha are considered as acceptable losses for the environment and for the farmer. This observation has been made in the experimental farm of De Mark, located close by Winterswijk (Koos Verlop, personal communication 2012). Thus, the three farm types are having a balanced nitrogen use. It is important to remind that it concerns organic farms, making carful use of organic fertilizers.

Figure 31: Farm gate phosphorus balance



Source: Nowak, 2012

Keeping a positive soil phosphorus balance is important not to mine soil resources and cause crops deficiency. Figure 31 shows a positive balance at the farm scale but cannot permit to conclude on fertilization practices. If fertilization is excessive, the soil might become saturated over the long run. Phosphorus is barely labile and is stored in the soil. However, when the soil becomes saturated, there is a high risk of losses per leaching and pollute ground water. Globally, the trade-off is to provide crops with sufficient fertilization but avoid excesses that decrease production efficiency and increase environmental risks in the longer term.

Objective	Sub-objective	Criterion
Acceptable environmental performances	Increase biodiversity	Importance of permanent grassland

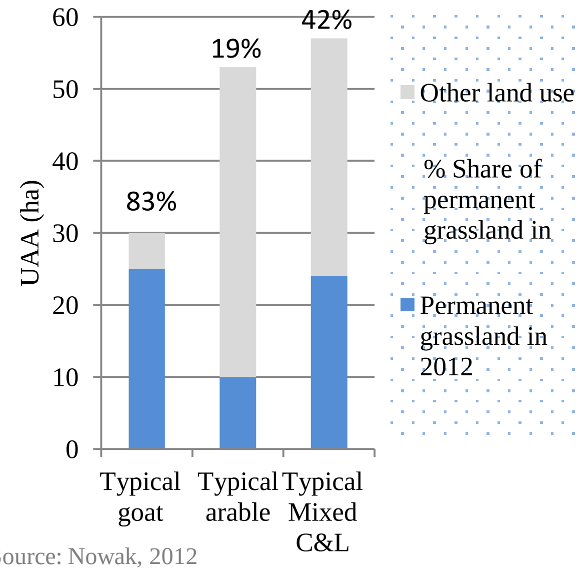


Figure 32: Proportion of grassland in farms' UAA

Source: Nowak, 2012

Figure 32 shows mainly two results; the absolute amount of grassland and its relative proportion in each farm type. From a farming systems perspective, the surface has more value than the actual proportion and farm management of grasslands is influenced by surfaces. However, from a regional perspective, the proportion has more value that the surfaces within each farm. If we imagine a region composed solely of goats or mixed farms, the total amount of grassland, and therefore the capacity of the area to support biodiversity, would vary according to the proportion of permanent grassland within each farm. COP farms have a low value from both perspectives and therefore are considered as “worse” for natural biodiversity than the two other types of farms. However, depending on the use of “other land use”, it would be possible to characterize agricultural biodiversity as well and perhaps notice important differences between typical farms.

Objective	Sub-objective	Criterion
Reduce dependency on external inputs	Increase self-sufficiency	Forage autonomy

Livestock density is used here to assess the extent to which a farmer is autonomous in forage. However, the number of hectare per animal required to be autonomous in forage varies according to livestock but also to pedo-climatic condition and pasture productivity. Additionally, it concerns organic farms which benefit significantly of forage autonomy. Thus, pastures have very low stocking density, as shown in table 20, and are integrated in a grazing rotation most of the year. Some pastures are kept to make hay for the winter and most farms are autonomous in forage. An important feature that justifies this low stocking density compared to Dutch agriculture is the more important use of forage for animal nutrition and less brought-in concentrates.

Table 20: Livestock density in typical farms of the Ribéracois

	Typical goat farm	Typical arable farm	Typical mixed farm
Stocking density (LU/ha)	0.4		0.3

Source: Nowak, 2012

4. INTERPRETATION AND DISCUSSION

4.1. Interpretation of results in Winterswijk

The results are summarized for the two case studies in tables 21 and table 22 by “rating” their performances for each indicator. Farm types receive “+”, “0” or “-“according to their performances in comparison to the chosen reference value. Indicators applied to FADN dataset use reference values such as group average for all farm types or a selection of farm types (Cf. Table 12). On the contrary, indicators applied to local data are rated by expert knowledge and I do not define thresholds and reference values. Additionally, in each case study, the potential to develop mixed farms is discussed. The two levels of analysis are differentiated and the color code remains the same as for previous sections. Grey cells indicate missing or inappropriate data.

Table 21: Summary of results obtained for the Netherlands and Winterswijk municipality

			Representative farms		
	Indicator	Reference value	Spe. OF	Spe. milk	Mixed C&L
FADN level	Energy spent per hectare of UAA	776.2 €/ha	++	++	++
	Energy spent per monetary unit of outputs	0.046 €/€	+	0	0
	Proportion of home-grown stuff in farms’ specific costs	2.1%	++	-	0
	Production efficiency	3.1%	+++	-	--
	Agro Environmental payments per hectare of UAA	15.6 €/ha UAA	0	++	0
	Share of subsidies in the gross farm income	16.2%	+	--	-
	Capacity to honor debts	4.76	+	--	0
	Labor remuneration of farm family members	12,400 €/FWU	+++	+	+
			Typical farms		
			Typical arable	Typical milk	Typical mixed
Local level	Nitrogen exported (kg N/farm/year)		None	Exports	None
	Phosphorus exported (kg P/farm/year)				
	N fertilization (kg/farm/year)		High	None	Low
	P fertilization (kg/farm/year)				
	Farm gate balance N in kg				
	Farm gate balance P in kg				
	(Permanent grassland in ha) / (UAA in ha)		None	High	Limited
	Stocking density (LU/ha)			High	High

At national level, Other Field crops farms have marked advantages for almost all indicators, except for biodiversity promotion, since they have very little grassland. Nevertheless, indicators of ecological structures could show the richness of buffer strips and hedgerows. Besides, dairy farms give many negative results (below the threshold) compared to other farm types and it seems that there is little incentive to start a new company (it is important to remind the very low income of 2009 which has a marked influence on other indicators). Their strong advantage is to keep important surfaces in permanent grassland which allows them to get high remuneration with agri-environmental measures and promote biodiversity. When looking at the production efficiency, mixed farms are rated lower than dairy farms because of their low efficiency in average compared to dairy farms. However, mixed farms are much more stable than dairy farms over three years. We can observe a similar trend for the labor remuneration of family members. Dairy farms and mixed farms are rated equally. The stability of income over the years in the case of mixed farms is compared to the actual amount of money earned which is higher for dairy farms. Income stability allows farmers to have a clearer view of investment possibilities and financial situation of the farm. However, in average over three years dairy farms have a higher income than mixed farms, and their investment potential is higher. Finally, mixed farms give average results for most indicators but do not show particular strong points. Nevertheless, they remain an interesting farming system.

At local level, dairy farms tend to do better than other farm types especially because they make use of their own manure and slurries. However, their manure production is higher than the allowed appreciation rates of 250 kg $N.ha^{-1}$ and surpluses have to be exported. This is not only an economical constraint for farmers but also a potential environmental constraint for the area. Similarly, arable farms import consistent amounts of mineral fertilizers. The reliance on petrochemical processes and importation of materials from far reaching places increases the environmental pressure. Thus, the use of dairy manure surpluses by local arable farmers would be a good opportunity to improve the profile of both farming systems. Mixed farms cannot cover the totality of their fertilization needs with their own manure and would benefit as well from an exchange with dairy farms. It would be interesting for mixed farms not to import fertilizers either and to adjust the number of animals to the cropped surfaces by enlarging slightly the size of the herd.

In the Netherlands, specialization has markedly gained the farming sector and it seems unacceptable for a farmer to come back to on-farm mixing systems. Mixed farms likely to be found are two specialized productions within one management unit. Moreover, incentives to start a field crop farm are a lot higher than to start a dairy or mixed farm. So the lack of incentives might be a barrier to their developments. Nonetheless, the large amount of money spent by farmers to export their manure is likely to be an important motivation for them to develop cooperation and between-farms mixing systems. Thus, Winterswijk seems to present a higher potential to develop communal or regional cooperation between specialized farms than true mixed farms. However, such cooperation can be achieved only through farmers’ commitment and society acceptance. An important leverage for action is to tackle first of all the economic perspectives of the cooperation. This is the major concern of farmers and they would change their practices at the sole condition that they see an economic benefit.

Environmental concerns are important for people living in Winterswijk which can help to start new cooperation with farmers. Finally, a number of practical details may also become major issues if such local manure transportations are to take place. As an example roads size, bad smell when spreading slurries, acceptance of traffic on the roads by the neighborhood etc. are important to consider.

4.2. Interpretation of results in the Ribéacois

Opportunities for mixed farms are discussed based on table 22, which summarizes the results obtained in the French case study.

Table 22: Summary of results obtained in Aquitaine and the Ribéracois

			Representative farms		
	Indicator	Reference value	Spe. COP	Spe. S&G	Mixed C&L
FADN level	Energy spent per hectare of UAA	108 €/€	+	++	+
	Energy spent per monetary unit of outputs	0.058 €/€	--	0	0
	Proportion of home-grown stuff in farms' specific costs	2.9%	-	++	++
	Production efficiency	- 13.6%	--	--	0
	Agro Environmental payments per hectare of UAA	13.3 €/ha UAA	-	++	-
	Share of subsidies in the gross farm income	52.4%	--	--	-
	Capacity to honor debts	2.26	+	++	++
	Labor remuneration of farm family members	7145 €/FWU	-	0	0
			Typical farms		
			Typical arable	Typical goat	Typical mixed
Local level	Nitrogen exported (kg N/farm/year)		None		
	Phosphorus exported (kg P/farm/year)		None		
	N fertilization (kg/farm/year)		Import	Self-sufficient	
	P fertilization (kg/farm/year)		Import	Self-sufficient	
	Farm gate balance N in kg		Balanced (>0)		
	Farm gate balance P in kg		Balanced (>0)		
	(Permanent grassland in ha) / (UAA in ha)		None	High	Limited
	Stocking density (LU/ha)			Low	

In Aquitaine, mixed organic farms show quite encouraging results compared to specialized arable and sheep and goats farms. They have several strong points such as the reliance on on-farm produced materials or a quite good capacity to honor debts and to invest according to their production capacity. Also, the labor remuneration per FWU is very low for arable farms and average for mixed and sheep and goats farms. This is important to consider and has a marked impact on the development of farming systems. The proportion of home-grown stuff is good for both systems (it is difficult to determine an optimal proportion of home grown materials), mixed and sheep and goats, and they make better use of available resources on the territory than arable farms do. However, whereas sheep and goat farms show very contrasted results for different indicators, mixed farms show stable average or good features. On the contrary, arable farms show homogeneous but low performances for almost all criteria. In comparison to the Netherlands, all farms exhibit very high dependency on subsidies, up to 80% of their incomes for sheep and goat and arable farms. This last consideration is also a stronger point for mixed farms which depends “solely” at 60% on governmental helps. Nevertheless, the overall profitability of agricultural production in Aquitaine is weak and depends highly on subsidies.

In the Ribéracois, mixed farms show very interesting characteristics for all parameters except a reduced acreage of permanent grassland compared to sheep and goats farms. It seems that crop diversity is emphasized before the promotion of natural biodiversity. Finally, arable farms exhibit a quite poor profile with very few strong points except for a balanced nitrogen and phosphorus use. Organic fertilizers are imported from Bretagne and they export their grains. Nevertheless, organic systems make more careful use of nutrient and promote soil organic matter build up by applying exclusively organic fertilizers. Additionally, the low stocking rate enhances forage self-sufficiency and the use of available resources.

In the Ribéracois, high value added production such as organic agriculture and short food distribution chains present good opportunities. It is also strongly encouraged by local politics (Agreste, 2010b) to support a positive image of agriculture and food in the area. Moreover, the area has a long history of farming systems diversification. However, possibilities for diversification are importantly influenced by the presence and convenience of local food distribution networks, cooperatives, silos or industries. This trend has a particular marked influence on the organic sector where farmers’ possibilities for conversion are directly dependent on the distance to buy their inputs and deliver their products. For instance, arable farmers need at least to have access in the neighborhood to a silo to deliver grains. A few years ago, some arable farmers of the area were willing to drive up to 100 kilometers to deliver organic grain to the silo (Benjamin Nowak in interview, 2012).

Typical farms exhibit low potentials for the development of between farm mixing if we consider only organic farms. The major reason is that manure is not considered as a waste but as a precious resource of organic matter and the farm structure allow them to make use of all manure and slurries. Thus, the only chance to develop between farms mixing in this region would be to import manure from neighboring conventional farms (under certain condition stated by the organic regulation). Also, the fact that the Ribéracois spread over a large territory makes these exchanges difficult to set up and increases costs for transportation. Concerning the promotion of on-farm mixing, keeping animals is an important constraint and farmers, or their children, tend to develop arable farms instead of animal farms because they are more convenient (it is possible to take holidays and a substantial amount of time is spent on the tractor). Young generations wish to have holidays and fewer constraints.

Therefore it is difficult to promote the development of mixed farms and only few farmers will accept the constraints by conviction or by passion (Emanuel Marseille[32] in interview, 2012).

4.3. Lessons learned from two case studies

Both case studies gave quite different outcomes and tend to favor different types of mixed farms. While the Ribéracois shows a better potential to develop on-farm mixing, Winterswijk tend to favor the development of between-farm mixing. Additionally, the difference in reliance on subsidies between the Netherlands and Aquitaine is striking and may compromise the development of farming systems in France. This last point is quite regretful and it could be useful to promote efficient farming systems to sustain their existence over the next decades.

In order to assess the theoretical potential for material exchanges between specialized farms, surpluses and uses of nitrogen and phosphorus are expressed for each farm type. However, these indicators simply show the potential need and surpluses of farms but do not allow to conclude about the feasibility of such exchanges neither about the willingness of farmers to go for such partnership, or about the distance between the two farmers. The distance between manure source and manure user as well as between the farm and the origin of inputs and destination of outputs is primordial. This information enables to calculate district or landscape wide nutrient balances. Fluxes intensity within the region as well as efforts made by the community to promote material exchanges and close nutrient cycles is important criteria to evaluate improvements. This last consideration is the main issue that will determine whether nutrients cycles will be shortened or not and practical ways to reach it. Task 3.2 of CANTOGETHER will be carried out with GIS models to analyze such possibilities. Additionally, in order to encourage interactions between farmers, workshops and focus group need to be organized. This is the assignment of WP1 and it will only occur in case studies where a strong design methodology is implemented.

Regardless of the CS location, farmers must have the choice to join or not and take the decision by themselves to implement innovative practices. The fact that economic incentives are the decisive parameter for farmers to take the move is a major commonality of all European farmers because they primarily need to earn a decent revenue out of his/her professional activity. There would be no reason for a farmer to invest time and energy in a project that do not claim direct benefits. A comprehensive approach can be adopted which makes use of simple calculations. The money spent by farmers for mineral fertilizers can be compared to the price of equivalent fertilization with locally produced organic materials. If it is not possible to offer farmers a lower price for slurries than for mineral fertilizers then the implementation of exchanges is not viable and has little chance of success. Also,

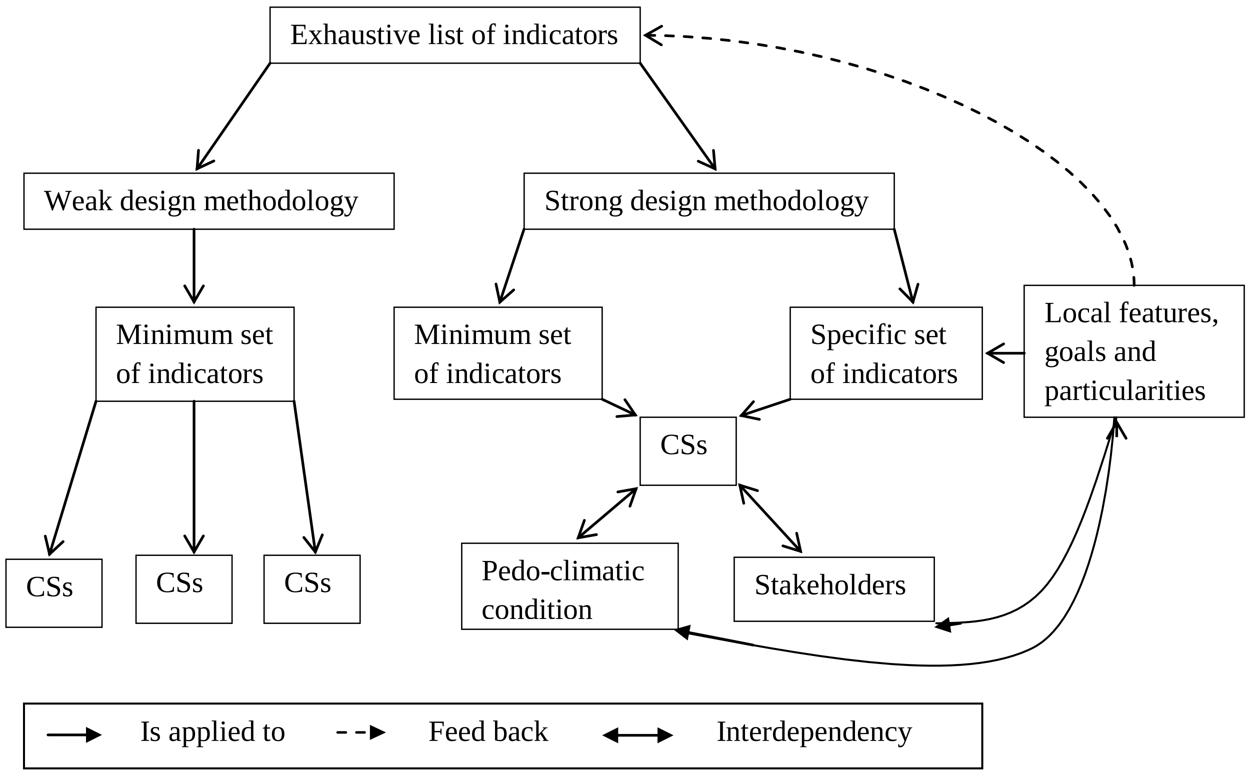
[32] Emanuel Marseille is the director of AgroBio Périgord, a local association for the development and promotion of organic agriculture. Benjamin Nowak, Thomas Nesme and I interviewed him about the future of organic and mixed farms in the Ribéracois.

such calculation has to cope with some practical constraints such as the variability of fertilizers prices indexed on oil price or the difference of location of all farmers. Then, farmers can receive a brochure promoting the benefits of such innovative practice while emphasizing an economic perspective. Despite the commonality, farmers throughout Europe have primarily differences and are embedded in unique contexts. Nevertheless, this approach enables a start but do not guarantee any success. Many other barriers can rise up such as the complexity of the farming style, society acceptance or logistic restrictions.

Both cases are very different in terms of population density, productions types, surfaces, pedo-climatic, topographic and finally socio-economic conditions. All elements make the comparison between case studies intricate and the set-up of a harmonized methodology arduous. As an example, no economic and social data has been collected in the Ribéracois and it is not possible to carry out a sustainability analysis at the moment. The case study C10 is proposed by INRA-Bordeaux as part of the PhD thesis of Benjamin Nowak and focuses on N, P and K cycles in organic farming. Every CS considered in the CANTOGETHER project presents original interests and heterogeneous features and will challenge the methodology at each new application. Above all, the accuracy of information delivered by local data as well as by the FADN database play a key role in harmonizing the methodology. As shown in the description of both CS, FADN exhibits more satisfactory representativeness of farming systems in the Netherlands than in Aquitaine. One important reason is the number of farms having an economic size below €25,000. All in all, although differences make harmonization difficult, it is also the greatest richness of CANTOGETHER.

In order to make use of this richness, the challenge for all WPs is to define a minimum set of information required in all CS which enables all on-going tasks of CANTOGETHER to pursue their work during the next year. Additionally, a careful selection of a few CSs (probably 3) where strong design will be implemented will determine original features to be studied in-depth. As showed in figure 33, weak design will only apply the basic set of indicators while strong design will apply an additional set of specific indicators to make use of particularities of CS. This second step will bring up key insights on agricultural originalities to forecast future agricultural policies in Europe.

Figure 33: My perspective on the way strong and weak design fit with other WPs



4.4. Farming systems typologies

This two-scales methodology relies on two chief concepts of farming systems: representative farms and typical farms. While representative farms allow using databases to describe farming systems over wide areas, typical farms on the contrary focus on local farming systems and make use of on-farm collected data. This approach has been designed for two different purposes. First, FADN data permit to get a general idea of mixed farming systems in a region compared to more specialized systems. Additionally, the "homogeneity" of data collected in FADN throughout Europe enables to compare regions of Europe between them. Second, describing typical farms enables to understand the real potential to develop on- or between-farm mixing systems in a landscape/district considering their actual resources and production potential. Possible innovations will be based on such analyses rather than on FADN data.

Thus, more practical experience would be appreciated by testing the methodology on several other case studies of other bio-geographical regions of Europe defined in the CANTOGETHER project (Cf. figure 3).

The definition of farming systems is different in both concepts of typical and representative farms. While the rationale behind FADN classification is only economic considering the relative distribution of farm income originating from different production sources (Andersen et al., 2007), local analysis uses a more environmentally based classification, taking into account structural, environmental or production components. The dichotomy between farms typologies is an important issue and a relevant entry point to better articulate both levels. However, with the experience brought in this thesis it is not possible to determine an articulation between the two levels and in-depth attempt has been carried out by the SEAMLESS project (Janssen et al., 2009). SEAMLESS do not yield satisfactory outcomes and participation of member countries for a general implementation. Additionally, it is not the purpose of CANTOGETHER to articulate both levels, but rather to conduct two parallel assessments. Therefore, it is more important to have a good analysis capacity of single farms rather than dissipating energy to construct a typical farm typology (Minute of CANTOGETHER WP3 workshop, 2012). Up scaling will rely on real farms and it will be important to verify if the selected farms cover the observed variability in farm performances and if the simulated farms are truly typical (Vayssières et al., 2011).

This is a major issue in the CANTOGEHTER project to ensure a good typicality of selected farms that will enable a correct extrapolation of the results. Based on a dozen of scientific studies, Vayssières et al. (2011) denounce that in a majority of cases, the representativeness of simulated farms is not evaluated. It is very rare to see independent statistical evaluation of the representativeness of a typical-farm sample previously defined with experts (Vayssières et al., 2011). This fact is once more acknowledged in this thesis where no such statistical analysis has been carried out. Thus, in order to have a consistent set of typical farms through time and space, the article by Vayssières et al. (2011) proposes an interesting methodology that might be partly adapted to case studies involved in "strong design". Among others, farmers, researchers and other relevant stakeholders are asked to give their opinion on the typicality of typical farms. Other statistical techniques are used to evaluate the distance between typical farms and all farms (or a sample) of the selected farm type.

The construction of typical farms involves several critical stages, among which the translation of hypothesis or objectives into a set of variables used for typification and relevant for the exercise (Köbrich et al., 2003). The weighting of selected individual variables which influences clustering decision (Kostrowicki, 1977) is also of importance. Main variables providing a basis for identification of agricultural types include: main inputs and outputs and the social, operational, productive and structural attributes of agriculture (Kostrowicki, 1977). The typification exercise requires at the beginning the researcher to have some experience and knowledge of the area, to be aware of the objectives of the typification exercise and that quantitative information is available (Köbrich et al., 2003). In order to uniformly and properly characterize farming systems, the same variables should always be used. This last point is likely to challenge the methodology of task 3.1 and requires a good communication with other participants of the different work packages.

Thus, for typical farms to comply with scientific requirement, it is necessary to agree upon a common methodology to harmonize typical farm construction process.

Currently, objectives of the CAP are changing and shifted towards environment preservation, landscape quality and the vitality of rural areas. Therefore, the economically based typology of FADN is not suitable for future policy recommendation. Thus, Andersen et al. (2007) developed an environmentally based extension of the FADN typology by introducing new stratifying variables to adapt emergent needs of the EU in terms of environmental policies recommendation. "The new typology should provide a first basis for evaluation of the pressures of farming on the environment, but also a good base for assessing the economic performance of farms in connection to their environmental performance. Based on the former it is clear that an environmental typology of farms should be based on variables related to intensity of farming and to the presence of extensive farmland habitats such as permanent grassland and rough grazing." (Andersen et al., 2007, pp. 255). The definition of both dimensions as mentioned by Andersen et al. (2007) is further detailed in annex 15. This new framework may provide interesting possibilities to give more coherence to CSs assessment.

In line with this assessment, it appears essential for CANTOGETHER WP1 and WP2 with its complete set of stakeholders to define accurate farm structure and management practices in appropriate case studies. On the quality of this commitment as well as the precision and the homogeneity of the assessment of farms, will depend the capacity of WP3 to make proper up-scaling of innovation and findings.

As shown by figure 33, the concept of typical and representative farms could be extended in some ways to the methodology utilized in WP1. If the "strong design" is to be implemented in one case study, the inquiry would rely more heavily on typical farms to find out local specificities of the CS and build on these. Typical farms allow dealing with matter of practical relevance for implementing innovative practices. On the other hand, representative farms are easy to get and could be better used for cases where only "weak design" is implemented. It might provide interesting insights on trends in European regions and to compare outputs of different CS although representative farms do not give deep enough insights on local settings to design innovative MFS.

While the weak design methodology could make use of a more complete set of parameters from the FADN database, strong design however could base a more reliable analysis on agri-environmental data.

4.5. Definitions of mixed farms

The definition of mixed farms is an important issue and has been barely tackled in this thesis. Solely figure 11 in section 2.6 briefly defines the way CANTOGETHER tackles this issue. The description of work gives the following definition: “mixed farming systems are a simultaneous utilization of crops and animals at the farm or regional level” (CANTOGETHER, 2011, p.5). However, a more practical definition could be necessary in the near future and be a source of misunderstanding between countries and case studies. Hence, a commonly accepted and more specific definition of mixed farms can be an important step towards harmonization. Conversely, it is also important to recognize MFS in their diversity. In this thesis, the definition used is on the one hand a goal oriented definition, projecting CANTOGETHER vision, and on the other hand the definition of FADN. For FADN and national databases, a farm is considered as a “mixed farm” when more than two thirds of the income comes from a combination of production sources (Andersen et al., 2007). Thus, this definition considers an extensive dairy farm self-sufficient in forage for their animals and applying the totality of its manure and slurries on pastures as a specialized dairy farm. In the same category we will find intensive dairy farms, importing most of the feed for animals and exporting slurries. This for the simple reason that the definition is based on economic criteria.

Conversely, CANTOGETHER is looking for a definition more based on environmental parameters and which would consider, among other parameters, nutrient and energy fluxes within the farm. From the example above, the first farm described would be considered as a mixed farm, even though their income is entirely based on milk production. The definition may benefit from a stocking rate threshold adapted to each CS which allows being autonomous in forage. Another possibility would be to quantify fluxes within the farm.

4.6. Selection, validation and interpretation of indicators

The methodology developed relies on a set of indicators. Therefore, the results, interpretation as well as the relevance of the methodology depend on the precision of indicators, their reliability or specificity. Thus, the larger the original set of indicators proposed, the more adapted to originalities of the CS the selection. This step depends on available indicators but also on available data on-site. A compromise between meaningful and feasible analysis is the trade-off to fit the purpose of CANTOGETHER as well as its accessible time and resources. The analysis based on agri-environmental indicators is of utmost importance and also the topic about which biggest concessions have to be made. Indeed, local data based on observation, interviews, workshops or measurements are very laborious to obtain and the choice of indicators for this analysis is particularly decisive for the efficiency and effectiveness[33] of the methodology.

Secondly, the "appropriate" number of indicators needed to compare mixed and specialized farming systems in a two level analysis is fully subjective. The larger the number of indicators, the better the analysis but also the longer. Thus, time needed to analyze case studies will be a decisive factor to choose the number of indicators which is possible to handle. Also, sufficient information should be provided to satisfy CANTOGETHER's requirements. It is interesting to note that the number of indicators using data from FADN is not so constraining compared to the number of indicators studied on-farm, which will have important repercussion on resource management. In this concern, the DIALECT method is very well adapted to the situation and can be carried out within one and a half hour with the farmer. It provides an interesting first assessment of the environmental profile of farms for all WPs to find out the information they need (Minute of CANTOGETHER WP3 workshop, 2012).

The content and purpose of local and FADN levels of analysis are also to be debated: what information should appear at each level? This is partly influenced by researchers' choices and partly by available data. For instance, FADN provides economic data and undermine social and environmental components. Thus, those data have to be collected on-site through agri-environmental indicators. Choices to balance the two levels might be also determined by the design selected in WP1 (strong or weak design) for a particular case study. We can imagine a methodology at several levels of precision according to the design selected, the motivation, resources and time of people in each CS. As an example, in Winterswijk, all on-going projects will stop in 2013 which makes it difficult and more expensive for CANTOGETHER to work with farmers. Since each CS is based on an existing project, the end of a project may hamper a proper implementation of innovative practices due to lack of time and budget.

During the WP3 workshop, it was decided that the final set of indicators selected in each case study should be partly identical and partly specific of the local situation according to the predispositions of each case study. For instance, available resources, willingness of farmers to participate, engagement of the local community but also and above all the availability of existing data are important to consider. The less data needs to be collected the higher the probability for the case study to be selected. At first instance, case studies were selected according to researchers' willingness to study the area. From WP3 workshop on, it rather considers their ability to provide information for a full LCA assessment or simply the DIALECT analysis and the availability of existing data to match requirements of WP 4 and WP5. A minimum set of data will be chosen by all tasks and will partly determine the selection of case

[33] Efficiency refers to the optimal utilization of resources while effectiveness refers to the suitability of the methodology to fulfill its role.

studies. The solution CANTOGETHER envisions to fit heterogeneous situation is to avoid generalization and to focus on punctual innovation.

The broader the set of indicators proposed by the task 3.1, the more flexible the methodology.

Once appropriate indicators are selected, their validation is a crucial step in the design process of a scientifically sound methodology. It is primordial for the set of indicator to be adequate for its specific purpose and therefore to be evaluated on this criterion. The methodological framework of Bockstaller and Girardin (2003), used as reference to structure the body part of this thesis, proposes a three ways validation for an indicator: i) a design validation where indicators are validated by pear review; ii) an outputs validation where indicator responses are compared to real world situation; iii) and an end-user validation to assert the usefulness of the indicator (Bockstaller and Girardin, 2003). The diagram in annex 12 summarizes these three validation processes. However, time is lacking as well as resources to carry out all three validation processes properly for the set of indicators chosen. Nevertheless, it is possible to consider the design validation as accepted, and that all indicators are scientifically sound. Indeed, most of them originate from the IDERICA framework, the DIALECT method or the FADN database and fit actual scientific requirements but also available data. Additionally, a usefulness test has been carried out by presenting my results to a group of researchers involved in WP3. These persons are the primary end users of the methodology and will discuss and select some indicators at more appropriate time (the workshop yielded only early conclusions and a set of indicators will be selected by September 2012). Finally, concerning the output validation it would be interesting for each indicator to collect data at both level, on-farm and from national and FADN databases in order to compare results obtained and get insights on how reliable the information supplied by the methodology is. Complementarily, stakeholders may also give their opinion about the validity of indicators, at least concerning the site-specific set of indicators.

Finally, for an indicator to be useful it is necessary to establish a reference value (Halberg et al., 2005). The reference value can be set up by stakeholders or end-users but might also be defined between scientists and policy makers (Bockstaller et al., 2008). There is no universal rule to define who is responsible of such choice and the procedure may change according to the context. In the methodology developed here, both levels of analysis, making use of different data sets, require an appropriate method to select a reference value. At the FADN region level, all information relies on the FADN data set and most reference values I choose are averages of all farm types in the given FADN region. From time to time, when this value is judged inadequate, an adapted average that excludes one or more farm types is preferred. Thanks to the reference value, the results of indicators for different farm types are judged high or low, good, bad or average. The validity of this procedure is arguable and the analysis and interpretation of such indicator is uncertain. Therefore, it is always better to draw out conclusions of such analyses with good knowledge of the practical situation in each CS and pick up relevant issues and particularities.

For local data, it is often difficult or impossible to set up a single reference value. I judged more coherent to qualify the results for each farm type and for every indicator according to "expert judgment". Indeed, this judgment is already at the origin of typical farm design and therefore, in a matter of consistency, this procedure might be kept to evaluate and compare farming systems between them. Not surprisingly, results can vary significantly between expert and cautious use of such an interpretation should be made. However, this judgment is only useful for researchers and farmers can better use the concept of benchmarking[34] (Halberg et al., 2005) the purpose of which is to encourage farmers to learn from other farms with better performances for a given indicator (EEA, 2001). Thus, this process of continuous improvement entails "the process of identifying best practices, understanding differences between farms, learning from an analysis of the reasons for this difference, setting goals for oneself based on the results achieved by others, and hence improving own practices" (Halberg et al., 2005, pp.40). Benchmarking provides more flexibility to define reference values based on local evaluation of farmers themselves. The empowerment of farmers is put forward to improve themselves their practices. One important step is the establishment of local technical and economic references with which farmers can interpret, compare and understand their own performances and search for improvement (Halberg et al., 2005). In France for instance, such references can be provided by the "Chambres d'agricultures" or regional technical journals and associations such as "AgroBio Périgord".

4.7. From farm to district level

As it has been described in the research question, the thesis compare mixed and specialized farming systems in order to interpret the possibilities to develop mixed farming systems at regional level. Thus, all indicators are based on farm level data and applied to describe three farm types. From this analysis, it is interesting to explore the possibilities for further development of the methodology and further interpretation of the results obtained at farm level to analyze trends at regional scale. This last point is precisely the goal of task 3.1 that takes into consideration interaction between farms within a "farming region". At this scale, it is possible to study farms interaction and their impacts on consumption of resources, pollution, exchange of services such as grain, straw, fodder and manure or even sharing land and equipment (Prayraudeau and Van der Werf, 2005). In this section, we are going to point out some bottlenecks and hindrance factors of up-scaling procedure.

[34] Benchmarking is the process of improving performance by continuously identifying, understanding and adapting outstanding practices and processes found inside and outside the farm (EEA, 2001).

To pass from the level of the farm to that of a farming region it is possible to carry out a partial survey by defining a farming typology and extrapolate results of a sub set of farms to the rest of the region (Prayraudeau and Van der Werf, 2005; Bechini et al., 2011). This is exactly the purpose of typical farms, to represent groups of farms to which innovations could potentially be transferred. There are several ways of proceeding to upscale indicators but a logical starting point in line with the study of Bechini et al. (2011) is a set of farms on which accurate measurements will be carried out. Here again, the commitment of WP1 and WP2 to inform on data availability and collection as well as potential innovation is crucial. Each of these farms, or in our case a typical farm, represents a cluster or a farm type and it is assumed that these groups of farms have homogeneous practices, structures and more generally, the same "environmental profile". It is theoretically possible to "duplicate" or transpose an innovation in a typical farm to a belonging to its cluster. However, each farmer has specific practical constraints and up scaling will be many times challenged.

Scaling is characterized by three dimensions: space, time and complexity (De Vries et al., 1993 cited in Bechini et al., 2011). Uncertainty in spatial up-scaling is due to an increasing number of farms with uncertain information. It is linked to the concept of typical farm. Up-scaling in complexity entails an increasing uncertainty as well as a decreasing quality of data when information is generalized. Up-scaling in time means to increase uncertainty by forecasting future trends according to past and present tendencies. Additionally, up-scaling in time include the use of data over several years to make the data set more robust for short time changes due to weather conditions or prices fluctuations. It is important to note that up scaling of agri-environmental indicators from farm to regional level is very sensitive to input data (Bechini et al., 2011) and therefore, the quality of the extrapolation relies importantly on the description of typical farms or the typicity of the real farm chosen. Three types of inputs that influence the results of indicators and therefore the result of up scaling are differentiated. Inputs can be measured, estimated by experts or taken as an average value of the cluster to which the farm belongs (Bechini et al., 2011). Hence, the bigger the scale, the more measured data it is possible to have and the more we up-scale, the more average values are used (Bechini et al., 2011). In other words, uncertainty increases with increasing up-scaling.

All results provided by indicators are strongly dependant on entry data and uncertainty is reflected in the response of an indicator. We can distinguish 4 main uncertainty sources: i) errors in input measurement; ii) errors in inputs estimation; iii) variability not taken into account such as within-field variability and; iv) the differences between the scale at which the assessment is made and the scale at which inputs are available (Bechini et al., 2011). Thus, if uncertainty levels are not known it is hard to tell to what extent the results are trustable and to what extent it is possible to extrapolate them. Interpretation of results are more difficult and the up-scaling procedure even vaguer. Additionally, changing scales and objectives have an important influence on the choice of indicators and their units.

For instance, while regional impacts such as eutrophication would be better represented by an area-based indicator, more global impacts such as CO2 emissions would better be expressed in terms of product-based indicators (Halberg et al., 2005). Often, in order to comprehensively characterize impacts from food production it is interesting to have both indicators for their look at the reality from two complementary angles.

Finally, when coming to study entire farming regions, local stakeholders will play an increasingly important role in the decision-making process. What are the goals to be reached and which impacts of farming systems will be addressed in priority? These are political decisions depending on a local, regional and national contexts and the discourses in society (Halberg et al., 2005).

4.8. Perspectives for the methodology

According to the research question settled at the beginning of the study, the methodology should provide the possibility to compare the sustainability of mixed farming systems with specialized farming systems. In fact, the methodology provides a set of criteria, arguably sufficient and relevant, to compare mixed and specialized farming systems between them. However, it seems impossible to talk about sustainability assessment when predominantly economic indicators are taken into account, making primarily use of FADN data. Then, certain environmental data are basically economic indicators interpreted from an environmental perspective (such as agri-environmental measure per hectare). Finally, social indicators are totally absent of the analysis and labor remuneration is the only social parameter taken into account. Thus, an important step towards a sustainability assessment would be to integrate more agri-environmental indicators and to take into account the social setting, especially at regional level. This last point has been mentioned during WP3 workshop and acceptance by the society of innovations will be an important factor to consider.

The second part of the research question concerns the interpretation of impacts of different farming systems at the landscape level in order to assess the potential for developing mixed farms. The up scaling of the methodology to a district or landscape level is quite fuzzy and unclear at the moment. This second phase of the research should be discussed in more details in task 3.1 running until November 2012. Nevertheless, it is possible to better understand some relationship and process at regional level such as land use patterns, soil organic matter, nutrient fluxes or the possibility for material exchanges. However, many gaps remain when looking back at the CANTOGETHER proposal and I must acknowledge the incapacity of the methodology to deal with numerous issues such as the possibilities to implement biogas plants, to study flows of energy and carbon, to assess erosion risks, to evaluate the potential for renewable energy production, to determine the efficiency of biomass conversion or the ecological and economic impacts of sustainable energy crops etc. (CANTOGETHER, 2011).

The lack of articulation between the two levels of analysis is an important methodological issue and perhaps an essential step to bring forward. A first possibility to do so would be to use national data to adjust and precise both levels of analysis and evaluate their distance. Presently, national data are mainly used to consolidate local analysis of farming systems. The gap between local and FADN level might be partly bridged by comparing both levels to national datasets. Additionally, it might provide useful insights to explore the gap between those data to see in which FADN farm type typical farms fit. However, as mentioned in section 4.4, the SEAMLESS framework was an attempt to harmonize at European level the FADN dataset for environmental purposes. The results are too complex and the method has suffered from a lack of commitment of European countries. Also, the enormous amount of data is too expensive to store and too laborious to handle. Data heterogeneity in the two regions represents a strong limiting factor to harmonize approaches. We have now briefly discussed the situation in two east-European countries but it still does not show the huge contrast we may find between other case studies of CANTOGETHER. The methodology relies on these two cases to compare mixed and specialized farming systems but will most probably not suit other areas due to important heterogeneity between case studies.

Nevertheless, it is a continuous process to improve a methodology and the search for more suitable indicators is an important activity for further improvements. More accurate and suitable indicators can be found in the literature and existing experiments. At the moment, the set of indicators predominantly comes from the IDERICA framework, the DIALECT method and the FADN database. It would be interesting to extend the set of indicators to work on specific issues of particular CS. As an example, having an appropriate and accurate set of indicators to work on water quality in Spain and in Brittany or increasing protein self-sufficiency in Sweden (Minute of CANTOGETHER WP3 workshop, 2012).

The workshop for WP3 held in Wageningen was an excellent occasion for me to present part of my results and get precious feedbacks from participants. It was interesting to see how and who could use my work. Some points of discussion that came up during these two days follow:

- Indicators selected can be used by different WPs. IDERICA indicators matching the RICA database are going to be used by WP 5, focusing on the economic analysis. DIALECT indicators, and in fact the entire tool will be used in WP 3 to examine and select a minimum set of data to be collected in all case studies.
- The approach brings interesting discussions to consider up scaling innovations. Also, the concept of typical farm as a basis for up scaling will not be adopted in CANTOGETHER because it is too much time consuming and extrapolation will rely on existing farms, willing to

cooperate and change their practices. The up-scaling procedure has not really been clarified and further study is needed.

- The FADN analysis stands by itself and there is no link between local analysis of real farms and global analysis of territories. The articulation of both levels is not feasible for it would need a too extensive study. Also, the SEAMLESS project tried to harmonize throughout Europe farming typologies to make environmental policies but the mainstream use of the results failed due to the immensity of the task and a lack of budget and of commitments from all countries. This assertion closed the discussion on the methodology.
- It appears that one major objective is missing. The acceptance by local community has been discussed within several topics and presents a major issue. The key to success to implement innovative practices and exchanges of materials between farms has to pass by an acceptance of the local community. Therefore, everybody acknowledged the lack of social indicators at regional level.

4.9. Remarks concerning the CANTOGEHTER project

Globally, this thesis has interesting consideration for several WPs. However, I misunderstood the primary goal of task 3.1 to find out what data should be collected in strong CS and how to upscale them. In fact, the purpose of task 3.1 stayed unclear during most of my thesis and it is finally decided to postpone deliverable 3.1 to November 2012. The start of the project was difficult and many questions have been clarified during the first six months, especially concerning the relation and information flows between all WPs. Thus, a stronger emphasis on the local analysis and agri-environmental indicators would have better fulfilled the objective of task 3.1.

Conclusion

In this study, the aim was to create a methodology, composed of a unique set of indicators, in order to compare the sustainability of mixed and specialized farming systems and to test the methodology in two case studies. For this methodology, data are analyzed at FADN and at local level. At FADN level, it is possible to use a harmonized set of indicators to carry out the economic analyses. However, at local level, it is not possible to use a single set of indicators for several reasons. First, due to the data heterogeneity of case studies, the collection of all necessary data would be too laborious and too expensive for CANTOGETHER. Secondly, it is more important to make good use of existing data and specificities of each case study rather than to harmonize the set of indicators. Nevertheless, a selection of a primary set of information, required by all work packages is necessary to have a common basis to work. To get started, partners of WP3 will test the set of indicators provided by the DIALECT method (Solagro, 2011). Nevertheless, further arrangements will be needed to harmonize approaches of all WP. Concerning the up scaling procedure, typical farms are two complex and time consuming to design. Therefore, all innovation will potentially be spread by farmers themselves or by extension services once the project ends. The project focuses on punctual innovations in various regions of Europe that will serve as basis for further independent studies afterwards. The commitment and interest of local stakeholders is a key to ensure such implementation.

Sustainability is a key guideline throughout the project and it is also specified that the methodology should compare the sustainability of different farming systems. However, all in all, the methodology in its present form cannot be considered as having satisfactory social and environmental perspectives. Further work is needed regarding the assessment of social acceptance of potential innovative practices. Additionally, a more complete set of environmental parameters would provide a greater flexibility and accuracy to the methodology. Several specific indicators concerning the price of manure handling, or the quality of water for instance are needed to assess between-farm mixing potential. To work on additional case studies would greatly benefit the methodology. Some major issues remain such as the lack of articulation between FADN and local analysis, the difficulty to upscale results obtained at farm level and the incapacity of the methodology to deal with several specific issues mentioned in the proposal of CANTOGETHER such as the implementation of biogas plants, the assessment of erosion risks, the scope for renewable energy production etc.

In practice, the application of the methodology gave contrasted results. In the Dutch CS, the advantages for mixed farming seem limited and there is more incentive to start a specialized dairy or arable farm. Thus, innovation is rather going towards communal or regional cooperation between specialized farms at the condition of economic viability of material exchanges and social acceptance of between-farm cooperation. On-farm mixing however presents very poor opportunities with little incentives for farmers. On the contrary, the French case study presents a good potential for the development of on-farm mixing and the Ribéracois has a long history of diversification. Between-farm mixing is constrained by the size of the territory and the difficulty to implement exchanges of materials between farms. Besides, organic farms have no manure surpluses due to their adapted stocking rate to their cropped and grazed surfaces. Nevertheless, keeping cattle or sheep imposes significant constraints to farmers, who are even less willing to accept them. Young farmers have more incentive to start specialized arable farm rather than mixed or dairy or breeding farms.

Although the CANTOGETHER project is ambitious in its complex structure by networking many different organizations as well as in its objectives, the restricted budget and time scale may be an issue concerning effective on-farm implementation of innovations. First the restricted budget implies a restricted number of case studies based on existing research programs but also a tinier flexibility to create site-specific innovations. The relatively short time scale will constraint the possibilities for implementing, guiding and readjusting these innovations and extension work will be up to the small and medium enterprises (SMEs) once the project is done. Finally, long term performances and impacts of these new systems are not included in the strategy. Additionally, the project is mainly designed from an economic and environmental point of view even though research strategy includes participatory approaches to collect information but also to release and disseminate the results. Moreover, from an economic perspective and in order to implement innovations, it seems to be essential to link the productions of farms with the market. In the design of farming systems sustainability, market linkage should include distribution, storage and consumption and could even be extended to health and other quality aspects. However, the focus on environmental issues alone does not allow having such a transversal view on the entire food chain and it might be difficult to assess a shift in production. Even from an environmental perspective, technical performances of MFS cannot overcome the market failure to value their environmental externalities and provide incentives to promote sustainability (IAASTD, 2008). Consequently, consumer awareness and market strategies are closely related to potential productions methods and should be integrated in the overall strategy to introduce new farming systems.

From the perspective of an agroecologist, this thesis was a great success for I had the opportunity to do research within the frame of a European project. It gave me the chance to experience what are the implications of harmonization in Europe with all sorts of advantages and disadvantages. Languages, cultures, climates, soils, people are very different within one country and even more from a country to another. The process of exchange and comparisons of farming systems and farming regions with other countries is very fruitful but asks enormous amounts of time and energy. Setting only uniform agricultural policies throughout Europe is nonsense in my opinion and the agricultural sector has a particularly important need of regionalization due to the wide heterogeneity of systems, soils, climates etc. The benefits of harmonizing agriculture in Europe are very debatable and especially from an environmental and social point of view. However, the issue is principally seen as an economic matter and will remain its foundations in the near future.

Bibliography

AgenceBio, 2010. L'agriculture biologique en France. http://www.agencebio.org/upload/pagesEdito/fichiers/CC_Ed2011_Aquitaine.pdf (accessed April 2012).

Agreste, 2010a. Recensement agricole 2010. http://www.agreste.agriculture.gouv.fr/recensement-agricole-2010 (accessed June 2012).

Agreste, 2010b. Agreste Aquitaine, recensement agricole 2010, analyse et résultats. http://agreste.agriculture.gouv.fr/en-region/aquitaine/ (accessed May 2012).

Altieri MA, 1989. Agroecology: A new research and development paradigm for world agriculture. Agriculture, Ecosystems and Environment 27 (1-4): 37-46.

Andersen E, Elbersen B, Godeschalk F, Verhoog D, 2007. Farm management indicators and farm typologies as a basis for assessments in a changing policy environment. Journal of Environmental Management 82 (3): 353-362.

Bechini L, Castoldi N, Stein A, 2011. Sensitivity to information upscaling of agro-ecological assessments: Application to soil organic carbon management. Agricultural Systems 104 (6): 480-490.

Blackburn H, 1998. Mixed farming systems and the environment: Livestock production, the environment and mixed farming systems. http://www.fao.org/WAIRDOCS/LEAD/X6130E/X6130E00.HTM (accessed December 2011).

Bockstaller C, Girardin P, 2003. How to validate environmental indicators. Agricultural Systems 76 (2): 639-653.

Bockstaller C, Girardin P, 2007. Mode de calcul des indicateurs agri-environmentaux de la methode INDIGO. Unpublished INRA Internal Technical Report. Colmar, France, 117p.

Bockstaller C, Guichard L, Makowski D, Aveline A, Girardin P, Plantureux S, 2008. Agri-environmental indicators to assess cropping and farming systems. A review. Agronomy for Sustainable Development 28 (1): 139-149.

Bos JFFP, Van de Ven GWJ, 1999. Mixing specialized farming systems in Flevoland (The Netherlands): agronomic, environmental and socio-economic effects. Netherlands Journal of Agricultural Science 47 (3): 185-200.

Brady NC, 1990. Making agriculture a sustainable industry. In: Edwards CA, Lal R, Madden P, Miller RH, House G (eds). Sustainable agricultural systems. Soil and water conservation society, Iowa, United States, pp. 20-32.

Bruinsma J, 2003. Selected issues in agricultural technology. In: Bruinsma J (eds). World agriculture: toward 2015/2030. An FAO perspective. FAO, Earthscan Publication Ltd, London, UK, pp. 297-327.

CANTOGETHER, 2011.Towards land management of tomorrow – Innovative forms of mixed farming for optimized use of energy and nutrients. Description of work. Collaborative project EU-FP7-KBBE-2011-5, INRA, Rennes, France.

CBS, 2010. Agricultural census. http://statline.cbs.nl/StatWeb/dome/default.aspx?LA=EN (accessed June 2012).

Dairyman, 2012. Region, Netherlands. http://www.interregdairyman.eu/regions/netherlands/ (accessed February 2012).

Darnhofer I, Fairweather J, Moller H, 2010. Assessing a farm's sustainability: insights from resilient thinking. International Journal of Agriculture Sustainability 8 (3): 186-198.

De Schutter O, 2010. Report submitted by the special rapporteur on the right to food to the General Assembly of the UN. Human Rights Council, Sixteenth session, Agenda item 3, Document A/HRC/16/49, 21p.

De Haan C, Steinfeld H, Blackburn H, 1996. Livestock and the environment: Finding a balance. FAO, US Agency for International Development and the World Bank, 115p. [Available at http://www.fao.org/docrep/x5303e/x5303e00.htm].

DRAAF, 2010. La Dordogne : Le département où l'agriculture rime avec culture. http://draaf.aquitaine.agriculture.gouv.fr/La-Dordogne-Le-departement-ou-l (accessed Mach 2012).

EEA, 2001. Environmental benchmarking for local authorities: from concept to practice. Environmental issue report, vol. 20., 64 p.

EC, 2011. Cap Reform – an explanation of the main elements. Memo/11/685. 12 October 2011. European Commission, Brussels, Belgium, 6p. [Available at http://europa.eu/rapid/pressReleasesAction.do?reference=MEMO/11/685].

Edwards CA, Grove TL, Harwood RR, Pierce Colfer CJ, 1993. The role of agroecology and integrated farming systems in agricultural sustainability. Agriculture, Ecosystems and Environment 46 (1-4): 99-121.

Eckert H, Breitschuh G, Sauerbeck DR, 2000. Criteria and standards for sustainable agriculture. Journal of Plant Nutrition and Soil Science 163 (4): 337-351.

Eurostat, 2011. Sustainable development in the European Union. 2011 monitoring report of the EU sustainable development strategy. Eurostat, European Union, Luxemburg, 375p.

FADN, 2012. Concept of FADN. http://ec.europa.eu/agriculture/rica/concept_en.cfm#fipcwa (accessed April 2012).

Feuz DM, Skold MD, 1991. Typical farm theory in agricultural research. Journal of Sustainable Agriculture 2 (2): 43-58.

Funes-Monzote FR, Monzote M, Lantinga EA, Ter Braak CJF, Sánchez JE, Van Keulen H, 2009. Agro-ecological indicators (AEIs) for dairy and mixed farming systems classification: identifying alternatives for the Cuban livestock sector. Journal of Sustainable Agriculture 33 (4): 435-460.

Girardin P, Bockstaller C, Van der Werf HMG, 1999. Indicators: tools to evaluate the environmental impact of farming systems. Journal of Sustainable Agriculture 13 (4): 5-21.

Girardin P, Bockstaller C, Van der Werf HMG, 2000. Assessment of potential impacts of agricultural practices on the environment: the AGRO*ECO method. Environmental Impact Assessment Review 20 (2): 227-239.

Girardin P, Mouchet C, Schneider F, Viaux P, Vilain L, 2004. IDERICA. Etude prospective sur la caractérisation et le suivi de la durabilité des exploitations agricoles françaises. Direction des Affaires Financières, study 04 F5 02 03, Institut national polytechnique de Lorraine, France, 72p.

Guillaumin A, Hopquin JP, Desvignes P, Vinatier JM, 2007. Des indicateurs pour caractériser la participation des exploitations agricoles d'un territoire au développement durable. OTPA, Lauréat de l'appel à projets innovants du CASDAR 2004, Chambre d'agriculture de Rhones-Alpes, France, 31p.

Halberg N, Van der Werf HMG, Basset-Mens C, Dalgaard R, De Boer IJM, 2005. Environmental assessment tools for the evaluation and improvement of European livestock production systems. Livestock Production Science 96 (1): 33-50.

Harwood RR, 1990. A history of sustainable agriculture. In: Edwards CA, Lal R, Madden P, Miller RH, House G (eds). Sustainable agricultural systems. Soil and water conservation society, Iowa, United States, pp. 3-19.

Herrero M, Thornton PK, Notenbaert AM, Wood S, Msangi S, Freeman HA, Bossio D, Dixon J, Peters M, van de Steeg J, Lynam J, Parthasarathy RP, Macmillan S, Gerard B, McDermott J, Seré C, Rosegrant M, 2010. Smart investment in sustainable food production: revisiting mixed crop-livestock systems. Science 327 (5967): 822-825.

IAASTD, 2008. Executive summary of the synthesis report. International assessment of agricultural knowledge, science and technology for development, Johannesburg, South Africa the 7-11 April 2008, 23p. [Available at http://www.agassessment.org].

ICSU, 2010. Earth system science for global sustainability: the grand challenges. International Council for Science, Paris, France, 20p. [Available at http://www.icsu-visioning.org].

IFEN, 2008. Les indicateurs globaux d'environnement et de développement durable. Synthèse des travaux réalisés pour le séminaire du Conseil scientifique de l'IFEN du 25 juin 2007 et compte rendu. Les dossiers IFEN 11, 48p. [Available at http://www.statistiques.developpement-durable.gouv.fr/publications/p/144/1097/indicateurs-globaux-denvironnement-developpement-durable.html].

Ikerd JE, 1993. The need for a systems approach to sustainable agriculture. Agriculture, Ecosystems and Environment 46 (1-4): 147-160.

Janssen S, Andersen E, Athanasiadis IN, van Ittersum MK, 2009.A database for integrated assessment of European agricultural systems. Environmental Science and Policy 12 (5): 573-587.

Kennisakker, 2012. Adviesbasis voor de bemesting van akkerbouwgewassen - Samenstelling en werking van organische meststoffen. http://www.kennisakker.nl/kenniscentrum/handleidingen/adviesbasis-voor-de-bemesting-van-akkerbouwgewassen-samenstelling-en-wer (accessed June 2012).

Klir GJ, 1991.What is system science?. In: Klir GJ (eds). Facets of systems science. Plenum Press, New York, London, pp. 3-7.

Köbrich C, Rehman T, Khan M, 2003. Typification of farming systems for constructing representative farm models: two illustrations of the application of multi-variate analyses in Chile and Pakistan. Agricultural Systems 76 (1): 141-157.

Kostrowicki J, 1977. Agricultural typology concept and method. Agricultural Systems 2 (1): 33-45.

Lang DJ, Wiek A, Bergmann M, Stauffacher M, Martens P, Moll P, Swilling M, Thomas CJ, 2012. Transdisciplinary research in sustainability science: practice, principles, and challenges. Sustainability Science 7, suppl. 1: 25-43.

López-Ridaura S, Van Keulen H, Van Ittersum MK and Leffelaar PA, 2005. Multiscale methodological framework to derive criteria and indicators for sustainability evaluation of peasant natural resource management systems. Environment, Development and Sustainability 7 (1): 51-69.

Meerburg BG, Korevaar H, Haubenhofer DK, Blom-Zandstra M, Van Keulen H, 2009. Review: The changing role of agriculture in the Dutch society. Journal of Agricultural Sciences 147 (5): 511-521.

Meinke H, Howden SM, Struik PC, Nelson R, Rodriguez D, Chapman SC, 2009. Adaptation science for agriculture and natural resource management – urgency and theoretical basis. Current Opinion in Environmental Sustainability 1 (1): 69-76.

Millennium Ecosystem Assessment, 2005. Ecosystems and human well-being: biodiversity synthesis. World Resources Institute, Washington DC, United States, 100p. [Available at http://www.maweb.org/en/Synthesis.aspx].

Ministere de l'agriculture, de l'agroalimentaire et de la foret, 2012. Les produits phytosanitaires. http://agriculture.gouv.fr/les-produits-phytosanitaires (accessed April 2012).

Naylor R, 2011. Expanding the boundaries of agricultural development. Food Security : the Science, Sociology and Economics of Food Production and Access to Food 3 (2): 233-251.

OECD, 2001. Environmental indicators for agriculture – Volume 3 Methods and results. OECD publication service, Paris, France, 409p.

OECD, 2010. Challenges for agricultural research. OECD Publishing, Paris, France, 305p. [Available at http://dx.doi.org/10.1787/9789264090101-en].

Oomen GJM, Lantinga EA, Goewie EA, Van der Hoek KW, 1998. Mixed farming systems as a way toward a more efficient use of nitrogen in European Union agriculture. Environmental Pollution 102 (1), suppl. 1: 697-704.

Prayraudeau S, Van der Werf HMG, 2005. Environmental impact assessment for a farming region : a review of methods. Agriculture, Ecosystems and Environment 107 (1): 1-19.

Rodriguez D, Sadras VO, 2011. Opportunities from integrative approaches in farming systems design. Field Crops Research 124 (2): 137-141.

Rufino MC, Hengsdijk H, Verhagen A, 2009. Analysing integration and diversity in agro-ecosystems by using indicators of network analysis. Nutrient Cycling in Agroecosystems 84 (3): 229-247.

Schaller N, 1993. The concept of sustainability. Agriculture, Ecosystems and Environment 46 (1-4): 89-97.

Schiere H, Kater L, 2001. Mixed crop-livestock farming. A review of traditional technologies based on literature and field experiences. FAO, Animal Production and Health paper 152, 73p. [Available at http://www.fao.org/DOCREP/004/Y0501E/Y0501E00.HTM].

Schiere JB, Groenland R, Vlug A, Van Keulen H, 2004. System thinking in agriculture: an overview. In: Rickert K (eds). Emerging challenges for farming systems – lessons learned from Australian and Dutch agriculture. Rural Industries Research and Development Corporation, Kingston, Australia, pp. 57-84.

Solagro, 2011. Manuel DIALECT. Rapport version 3 de janvier 2011, Toulouse, France, 61p. [Available at http://dialecte.solagro.org/]

Steinfeld H, Seré C, Groenewold J, 1995. World livestock production systems. Current status, issues and trends. FAO, Animal Production and Health paper 127, 58p. [Available at http://www.fao.org/DOCREP/004/W0027E/W0027E00.HTM].

Van der Meer HG, 2008. Optimising manure management for GHG outcomes. Australian Journal of Experimental Agriculture 48 (2): 38-45.

Van Keulen H, Schiere H, 2004. New direction for a diverse planet. Proceeding of the 4th International Crop Science Congress, 26 September – 1 October 2004, Brisbane, Australia, 12p. [Available at http://www.cropscience.org.au/icsc2004/].

Vayssières J, Vigne M, Alary V, Lecomte P, 2011. Integrated participatory modeling of actual farms to support policy making on sustainable intensification. Agricultural Systems 104 (2): 146-161.

Zahm F, Girardin P, Mouchet C, Viaux P, Vilain L, 2005. De l'évaluation de la durabilité des exploitations agricoles à partir de la méthode IDEA à la caractérisation de la durabilité de la « ferme européenne » à partir d'IDERICA. Colloque international Indicateurs Territoriaux du Développement Durable, 2 et 3 décembre 2005, Aix en Provence, France, 17p. [Available at http://www.idea.portea.fr/fileadmin/documents/En_savoir_plus/IDEA_IDERICA_colloque_aix.pdf].

Annexes

Annex 1: Detailed description of the Work Packages within the CANTOGETHER project

"**WP1** will identify and design innovative mixed farming systems satisfying environmental concerns for different European pedo-climatic zones using a participatory modeling approach together with farmers and supply-chain stakeholders. The mixed farming systems will be designed as a function of the i) pedo-climatic environment and main environmental issues, ii) livestock and crop diversification, iii) renewable energy production iv) conventional and organic systems, and v) socioeconomic demands. Agro-ecological, biotechnological and organizational innovations will be identified and designed using the expertise of recognized stakeholders. WP1 will gain advice and feedback from stakeholders to assist in the determination of stakeholder requirements, co-design and evaluation of innovative sustainable mixed farming systems and, in connection with WP6, will enable the transfer of information from the project to the intended end users in an effective manner.

Based on the portfolio farm-level case studies, **WP2** will evaluate and validate innovative combinations of agronomic and livestock practices. It will verify the feasibility of these combinations and provide useful data for in-depth assessments performed in WP4 and WP5. The fluxes and balances of nutrients will be specified, with a particular attention to nitrogen, phosphorus and carbon and to natural resources such as water, soil quality and non-renewable energy sources. At the landscape and district levels, **WP3** will test and validate new mixed farming systems and provide a focal point for the testing of innovative mixed agronomic and livestock practices on the portfolio of district and landscape level case studies. The fluxes of feed, nutrients and carbon fluxes at the district level will be specified.WP2 and WP3 will provide appropriate parameters for models used in WP4 and WP5.

WP4 will assess the environmental sustainability of the innovative mixed-farming systems under a range of agronomic, soil and climate zones and will compare output of the analyses to a corresponding assessment of current strategies. Using existing models and LCA analysis, WP4 will allow an overall evaluation of environmental impacts and provide robust data for the socioeconomic assessment in WP5. **WP5** will assess the profitability, gain and socio-economic viability of mixed farming methods developed in different systems (organic, low external input, integrated, etc.) across Europe. It will identify the acceptability of mixed-farming solutions amongst producers and supply-chain actors. WP5 also will analyze the existing policies supporting mixed farming and evaluate implications of the widespread adoption of mixed-farming systems to provide policy-scenario recommendations to the EU. An integrated assessment of mixed-farming systems will be performed based on environmental and economic outcomes to ensure optimization for both farmers and the larger society. This overall assessment will feed back to WP1 to improve the previous innovations.

WP6 will disseminate CANTOGETHER achievements and knowledge to the socio-economic stakeholders, especially farmers, farm advisors and rural extension services, other rural actors and policy-makers and to the scientific and learning community to promote innovations in agriculture.

WP7 will provide a strong management component that will allow CANTOGETHER to reach its ambitions.

Annex 2: Thoughts of an agroecologist

In order to get more insights on the way this topic fits as an agroecology thesis, we are going to answer the following questions: What makes this topic relevant in an agroecological, system thinking context? Furthermore, within this topic, what specific research objectives seem justified and which questions need to be answered? These two questions allow the elaboration of personal reflection on my thesis related to the field of agroecology. This reflexion gives to the agroecology master at UBM a basis to further elaborate on students' theses and promote action research. To be proactive is a crucial process for students to learn from their mistakes and take their own responsibilities to make choices (scientific or of other nature).

- Definition of agroecology

Studying the sustainability of farming systems requires adopting a comprehensive approach to research in order to improve existing systems and design new ones that are more sustainable (Plucknett, 1990). Agroecology has been proposed as a new scientific discipline that defines, classifies and studies agricultural systems from a biological, physical and socio-economic perspective (Altieri, 1989). Agroecology is concerned with the sustainability of food and farming systems at all levels and studies the interactions between and within plants, fields, farms, regions and the planet. Interactions between subsystems within and beyond farm boundaries embedded in their social context are the primary way to analyze agroecosystems (the inherent scale of analysis of a farming system).

Agroecology is defined as a practice, a science and a movement and covers several disciplinary fields such as agronomy, sociology, ecology, philosophy or education but also various organizations such as schools, extension agencies, research institutes and a multitude of field-oriented organizations. In order to implement groundbreaking, sustainable agroecosystems, socio-economic determinants that govern what is produced, how it is produced, and for whom it is produced (Altieri, 1989) must be re-discussed in a bottom-up approach and progressively integrated into larger aggregates within societies to form a harmonious whole. This process should be fully incorporated within politics and policies seeking sustainable development and encompassing social, environmental and economic changes.

- What makes this topic relevant in an agroecological, system thinking context?

The CANTOGETHER project aims at closing nutrient and energy cycles by relying on information gathered from finished or on-going projects but also through participatory approaches in several case studies. It basically fits within the philosophy of agroecology, representing one of the many ways to reach its goals. The fact that it is a European project makes it very interesting and attractive to promote agroecology, bridging the opportunity of widening its acceptability as a science and as a set of tools and methods.

For instance, system thinking is of utmost relevance in pluri-disciplinary research due to the large amount of information to be classified, taking various perspectives into account. System thinking is useful as well to transfer observation from the field and related experience with the literature. The frequent back and forth movement between the whole and the parts provides an effective method to understand a problem in its context. Additionally, the project looks at farming systems from an environmental, social and economic perspective. The use of system thinking is required to interrelate and balance economic, social and environmental issues in order to provide a “sustainability analysis”. Lastly, Work Package 3 focuses on an assessment at landscape level and studies the relationship of farms with their environments. Therefore, several components such as dynamic between people, local resources, socio-economic and pedo-climatic contexts are studied simultaneously.

As an academic field, agroecology has taught me to learn about myself and to understand learning and discovery processes. The systematic meta-analysis or meta-reflection carried out after each experience is of primary relevance in drawing final conclusions. The project as well as the action researcher gets important benefits from this activity.

- What specific research objective seems justified?

From the research objectives of task 3.1 (Box 1), the first one seems to be most appropriate or most relevant for it aims at a first general observation of those farms which are suitable for an ex-ante assessment. The performance of mixed farming systems at landscape level or district scale in comparison to conventional farming systems is an important entry point to draw out possible paths for innovation. Furthermore, it is a first entry to compare countries between them as well and notice major differences that influence possible evolution of the farming sector in different regions of Europe.

The second objective to evaluate the potential for and efficiency of different methods of cooperation between farms with regards to recycling strategies and biomass conversion in a district is interesting as it deals directly with the relevant issue of nutrient cycling and innovation. However, the deep analysis of methods to convert biomass will be further detailed in subsequent tasks of work package 3. The important goal of task 3.1 is for me first to understand and highlight specificities of different farming systems in their respective contexts and show the differences and similarities of mixed and specialized systems.

Third, it is useful for me as a way to deepen my understanding of the concept of sustainability through a European perspective and its implications at the farming system and landscape level. As part of an Agroecology thesis, this work presents an opportunity for me to experience action research and put forward current issues in European agriculture from an agro ecological perspective.

Annex 3: Economic size thresholds applied by the Commission (in ESU) from year 2008*

Country	ESU	€/ECU[35]
Belgium	16	19,200
Bulgaria	1	1,200
Czech Republic	4	4,800
Denmark	8	9,600
Germany	16	19,200
Estonia	2	2,400
Ireland	2	2,400
Greece	2	2,400
Spain	4	4,800
France	8	9,600
Italy	4	4,800
Cyprus	2	2,400
Latvia	2	2,400
Lithuania	2	2,400
Luxembourg	8	9,600
Hungary	2	2,400
Malta	8	9,600
Netherlands	16	19,200
Austria	8	9,600
Poland	2	2,400
Portugal	2	2,400
Romania	1	1,200
Slovenia	2	2,400
Slovakia	8	9,600
Finland	8	9,600
Sweden	8	9,600
United Kingdom	16	19,200
United Kingdom (Northern Ireland)	8	9,600

Source: FADN, 2012

*Since 2010, the ESU is expressed in euro and not in euro/ECU. Till 2009, one ESU is equivalent to 1,200 euro/ECU.

[35] A conversion rate (national currency - EUR/ECU) is calculated for each Member State for each FADN accounting year and is the average of the monthly exchange rates. These monthly exchange rates are calculated by Eurostat and made available as part of the CRONOS data bank (FADN, 2012).

Annex 4: FADN farm classification

Economic size classes	
1	< 2 ESU
2	2 - <4 ESU
3	4 - <6 ESU
4	6 - <8 ESU
5	8 - <12 ESU
6	12 - <16 ESU
7	16 - <40 ESU
8	40 - <100 ESU
9	100 - <250 ESU
10	>= 250 ESU

Source: FADN, 2012

TF14 (Types of Farming)	
13	Specialized COP
14	Specialized other fieldcrops
20	Specialized horticulture
31	Specialized wine
32	Specialized orchards - fruits
33	Specialized olives
34	Permanent crops combined
41	Specialized milk
44	Specialized sheep and goats
45	Specialized cattle
50	Specialized granivores
60	Mixed crops
70	Mixed livestock
80	Mixed crops and livestock

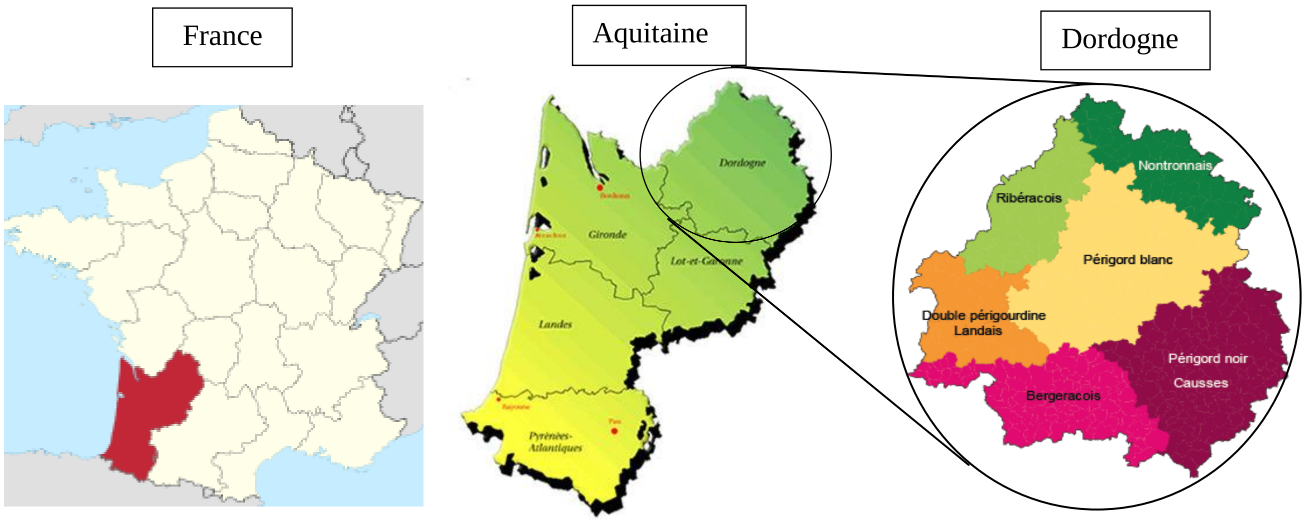
Source: FADN, 2012

Annex 5: Localtion of Winterswijk

Source : http://www.european-waterways.eu/e/info/netherlands

Annex 6: Pictures of Winterswijk

Annex 7: Location of “The Riberacois” (petite region agricole)



Annex 8: Municipalities constituting the Ribéracois

Codgeo	Libellé	Petite région agricole	Libellé
24007	Allemans	24158	RIBERACOIS
24033	Beaussac	24158	RIBERACOIS
24038	Bertric-Burée	24158	RIBERACOIS
24057	Bourg-des-Maisons	24158	RIBERACOIS
24058	Bourg-du-Bost	24158	RIBERACOIS
24062	Bouteilles-St-Sébastien	24158	RIBERACOIS
24090	Celles	24158	RIBERACOIS
24093	Cercles	24158	RIBERACOIS
24097	Champagne-et-Fontaine	24158	RIBERACOIS
24099	Champeaux-et-la-Chapelle-	24158	RIBERACOIS
24105	Chapdeuil	24158	RIBERACOIS
24109	La Chapelle-Grésignac	24158	RIBERACOIS
24110	La Chapelle-Montabourlet	24158	RIBERACOIS
24114	Chassaignes	24158	RIBERACOIS
24119	Cherval	24158	RIBERACOIS
24128	Comberanche-et-Épeluche	24158	RIBERACOIS
24131	Connezac	24158	RIBERACOIS
24141	Coutures	24158	RIBERACOIS
24144	Creyssac	24158	RIBERACOIS
24154	Douchapt	24158	RIBERACOIS
24178	Festalemps	24158	RIBERACOIS
24199	Gout-Rossignol	24158	RIBERACOIS
24200	Grand-Brassac	24158	RIBERACOIS
24203	Les Graulges	24158	RIBERACOIS
24209	Hautefaye	24158	RIBERACOIS
24214	Javerlhac-et-la-Chapelle-	24158	RIBERACOIS
24221	Rudeau-Ladosse	24158	RIBERACOIS
24235	Léguillac-de-Cercles	24158	RIBERACOIS
24247	Lusignac	24158	RIBERACOIS
24248	Lussas-et-Nontronneau	24158	RIBERACOIS
24253	Mareuil	24158	RIBERACOIS
24283	Monsec	24158	RIBERACOIS
24286	Montagrier	24158	RIBERACOIS
24303	Nanteuil-Auriac-de-Bourza	24158	RIBERACOIS
24319	Paussac-et-St-Vivien	24158	RIBERACOIS
24323	Petit-Bersac	24158	RIBERACOIS
24333	Ponteyraud	24158	RIBERACOIS
24344	Puyrenier	24158	RIBERACOIS
24352	Ribérac	24158	RIBERACOIS
24353	La Rochebeaucourt-et-Arge	24158	RIBERACOIS
24368	St-Antoine-Cumond	24158	RIBERACOIS
24391	St-Crépin-de-Richemont	24158	RIBERACOIS
24394	Ste-Croix-de-Mareuil	24158	RIBERACOIS
24403	St-Félix-de-Bourdeilles	24158	RIBERACOIS
24411	St-Front-sur-Nizonne	24158	RIBERACOIS
24434	St-Just	24158	RIBERACOIS
24451	St-Martial-de-Valette	24158	RIBERACOIS
24452	St-Martial-Viveyrol	24158	RIBERACOIS
24455	St-Martin-de-Ribérac	24158	RIBERACOIS
24458	St-Martin-le-Pin	24158	RIBERACOIS

24460	St-Méard-de-Drône	24158	RIBERACOIS
24477	St-Pardoux-de-Drône	24158	RIBERACOIS
24482	St-Paul-Lizonne	24158	RIBERACOIS
24490	St-Privat-des-Prés	24158	RIBERACOIS
24503	St-Sulpice-de-Mareuil	24158	RIBERACOIS
24504	St-Sulpice-de-Roumagnac	24158	RIBERACOIS
24508	St-Victor	24158	RIBERACOIS
24511	St-Vincent-Jalmoutiers	24158	RIBERACOIS
24529	Segonzac	24158	RIBERACOIS
24537	Siorac-de-Ribérac	24158	RIBERACOIS
24541	Soudat	24158	RIBERACOIS
24548	Teyjat	24158	RIBERACOIS
24553	Tocane-St-Apre	24158	RIBERACOIS
24554	La Tour-Blanche	24158	RIBERACOIS
24564	Vanxains	24158	RIBERACOIS
24565	Varaignes	24158	RIBERACOIS
24569	Vendoire	24158	RIBERACOIS
24573	Verteillac	24158	RIBERACOIS
24579	Vieux-Mareuil	24158	RIBERACOIS
24586	Villetoureix	24158	RIBERACOIS

Source: DRAAF, 2012

Annex 9: Picture of the Ribéracois

Annex 10: Definition of farm typology

“If the fundamental precepts of Farming Systems Research were to be taken literally then it would imply that for each farm ‘unique’ solutions should be sought. This is an unrealistic expectation, but it has led to the idea of a recommendation domain, implying creating taxonomy of farms, in order to increase the general applicability of recommendations“(Köbrich et al., 2003). When comparing farms with each other, groups are being designed according to farms similarities in order to synthesize and make reality more understandable. Such groups are called a typology and according to Kostrowicki (1977) are understood as:

(i) a more or less established form of crop growing and/or livestock breeding for production purposes, characterized by a set or association of its attributes (characteristics, features, properties).

(ii) a supreme and overall concept in agricultural classification comprising all other concepts used in classifying agriculture, such as land tenure systems, land use systems, cropping systems, systems of livestock breeding, farming systems, types of farming etc.

(iii) a hierarchical concept encompassing types of varying orders, from types of farms based on a study of individual holdings, through several intermediate orders to the highest order--types of world agriculture.

(iv) a dynamic concept, changing in an evolutionary or revolutionary way along with a change of its basic attributes. (Kostrowicki, 1977)

A typology is a hierarchical and dynamic concept in which types of a lower order may be grouped into types of a higher order, irrespective of their distribution in space and time (Kostrowicki, 1977). In agriculture, a farm is the best unit in agricultural typology, as it is the only real unit of operation (Kostrowicki, 1977). Finally, a typology permit to use farm level indicators as an integrated set rather than as single indicators (Andersen et al., 2007) and thereby to build coherent methodologies.

Annex 11: Definition of an indicator

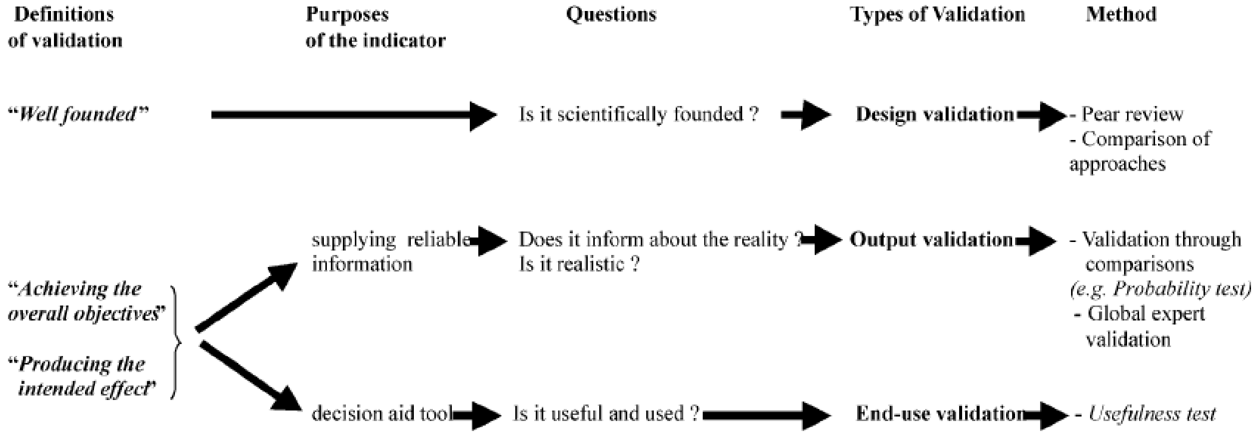
Indicators are variables which provide information on other variables more difficult to understand, they are used as benchmarks for decision making as well. Indicators remains a privileged tool to understand complex systems but are of interest, firstly, in comparison with a reference or a norm[36] (Girardin et al., 1999). Indicators cross borders between data and information, between scientific discipline and between science, politic and society (IFEN, 2008). Lopez-Ridaura et al. (2005) define them as qualitative or quantitative measure that reflects a criterion (a criterion being a standard on which a judgment or decision may be based).

According to IFEN (French environmental institute) (2008), indicators have three main functions: i) A scientific function, they should be specific, measurable, valid, accurate, simple, transparent, realistic, commonly admitted by the international community, available and accessible, sustainable and flexible and they should also be adapted to aggregation and models. ii) A political function by being related to strategic orientations, simple and comprehensive, referring to certain norms and values, usable for international comparisons and relevant regarding public policies. iii) A societal function which require indicators to be simple and communicable, related to popular concepts, catch attention, fostering action and central in public debates. They can be used for instance to assess the impact of agricultural systems on their environment. In our situation, indicators should respond to sustainable development characteristics and be able to represent the complexity of the sustainability concept at the farm and the landscape level.

Therefore, indicators should comply to sustainable development requirements and according to Zahm et al. (2005) indicators should be: i) systemic in order to apprehend simultaneously economic, social and environmental aspects of agriculture; ii) time and space bound to assess the potential impacts of the system in time and space; iii) ethical because sustainability rely on a value bound basis that preserve human and natural patrimony. Additionally, sustainability indicators should concern systems': i) viability which imply efficiency of the production system and the income security of the farming system regarding market's vagary and the incertitude from the direct payments; ii) livability if the farmer has a decent professional activity and his/her family have a decent life, we can consider revenue and working hours; iii) environmental reproducibility determined with agrienvironmental indicators that characterize farming practices impacts on the surrounding environment.

[36] Here, norm refers to an interval, a threshold or other reference value that enable a relative interpretation of the indicators' value.

Annex 12: A flowchart for the framework of indicator validation



Source: Bockstaller and Girardin, 2003

Annex 13: Description of used FADN variables

Variable headings	Unit	Description	Formule
SE025_Total utilized agricultural area UAA	ha	Total utilized agricultural area of holding. Does not include areas used for mushrooms, land rented for less than one year on an occasional basis, woodland and other farm areas (roads, ponds, non-farmed areas, etc.). It consists of land in owner occupation, rented land and land in share-cropping (remuneration linked to output from land made available). It includes agricultural land temporarily not under cultivation for agricultural reasons or being withdrawn from production as part of agricultural policy measures. It is expressed in hectares (10 000 m²).	(#48+#49+#50) / 100
SE035_Cereals	ha	Common wheat and spelt, durum wheat, rye, barley, oats, summer cereal mixes, grain maize, other cereals.	[K120(4)..128(4)] / 100
SE041_Other field crop	ha	Dry pulses, potatoes, sugar beet, herbaceous oil seed and fibre crops including seed (excluding cotton), hops, tobacco, other industrial crops (including cotton and sugar cane), grass seeds and other seeds.	{[K129(4)..135(4)] + K142(4) + K143(4)} / 100
SE071_Forage crops	ha	Fodder roots and brassicas (mangolds, etc.), other fodder plants, temporary grass, meadows and permanent pastures and rough grazing.	[K144(4) + K145(4) + K147(4) + K150(4) + K151(4)] / 100
SE073_Set aside	ha	agricultural policy measures. Includes both voluntary and compulsatory set aside but excludes the area of non food crops grown on set aside area.	[K146(4) if [K146(2) = 1 and K146(3) = 5 to 8] / 100
SE074_‘’	ha	Total agricultural area out of production	K314(4) / 100
SE075_Woodland area	ha	Woodland area, forests, poplar plantations, including nurseries. Not included in UAA (SE025).	K173(4) / 100
SE080_Total livestock units	LU	Number of equines, cattle, sheep, goats, pigs and poultry present on holding (annual average), converted into livestock units. Not included are beehives and other animals. Animals which do not belong to the holder but are held under a production contract are taken into account according to their annual presence.	[D22(5) * 0.08] + [D34(5) * 0.02]+ SE085 + SE090 + SE095 + SE100 + SE105
SE120_Stocking density	LU/ha	Density of ruminant grazing livestock: average number of bovine LU (except calves for fattening) and sheep/goat LU per hectare of forage UAA. Forage area includes fodder crops, agricultural fallows and land withdrawn from production (except when non food crops are cultivated), permanent pasture and rough grazing. Stocking density is calculated only for holdings with corresponding animals and with forage area.	{ SE085 + SE090 - [D23(5) * 0.04] + SE095 } / [[K144(4)..147(4)] + K150(4) +K151(4)] / 100
SE131_Total outputs	€	Total of output of crops and crop products, livestock and livestock products and of other output. Sales and use of (crop and livestock) products and livestock	SE135 + SE206 + SE256

		+ change in stocks of products (crop and livestock) + change in valuation of livestock - purchases of livestock + various non-exceptional products.	
SE132_ ‘Total output / Total input		Total output / Total input	SE131/SE270
SE206_Total outputs livestock and livestock products	€	= Livestock production + change in livestock value + animal products. *Livestock production* = Sales + Household consumption – Purchases (It is calculated for equines, cattle, sheep, goats, pigs, poultry and other animals.) *Change in livestock valuation* = value at closing valuation - value at opening valuation. For animals which are present on the holding for more than one year, the value corresponding to the increase in volume is estimated. *Animal products* = Sales + Household consumption + Farm use + (Closing valuation - Opening valuation). The products are: milk and milk products from cows, ewes, goats, wool, hens' eggs, other animal products (stud fees, manure, other eggs, etc.) and receipts from animals reared under a service contract (animals not owned by farmer) and honey.	SE216 + SE220 + SE225 + SE230 + SE235 + SE240 + SE245 + SE251
SE265_Farm use	€	Value of crop products produced and used on the holding to obtain other final agricultural products. The products concerned are mainly crop products used as feed for animals held on the holding, and seeds and seedlings produced and used on the holding. These products are taken into account in the amount of agricultural output. The cost items relating to feedingstuffs and seeds account for the major part of that amount.	K183(10)
SE270_Total inputs	€	= Specific costs + Overheads + Depreciation + External factors. Costs linked to the agricultural activity of the holder and related to the output of the accounting year. Included are amounts relating to inputs produced on the holding (farm use) = seeds and seedlings and feed for grazing stock and granivores, but not manure. When calculating FADN standard results, farm taxes and other dues are not included in the total for costs but are taken into account in the balance Subsidies and taxes (subsidies - taxes) on current and non-current operations. The personal taxes of the holder are not to be recorded in the FADN accounts.	SE281 + SE336 + SE360 + SE365
SE275_Total intermediat consumption	€	Total specific costs (including inputs produced on the holding) and overheads arising from production in the accounting year. = Specific costs + Overheads.	SE281 + SE336
SE281_Total specific costs	€	= Crop-specific inputs (seeds and seedlings, fertilizers, crop protection products, other specific crop costs), livestock-specific inputs (feed for grazing stock and granivores, other specific livestock costs) and specific forestry costs.	SE285 + SE295 + SE300 + SE305 +SE310 + SE320 + SE330 +

			SE331
SE290_Seeds and plants home-grown	€	= Seeds and seedlings produced and used on the farm.	#273
SE295_Fertilizers	€	Purchased fertilizers and soil improvers (excluding those used for forests).	#274
SE315_Feed for grazing livestock home-grown	€	Marketable farm products (including milk other than suckled) used as feedingstuffs for grazing stock.	#268
SE345_Total energy	€	Motor fuels and lubricants, electricity, heating fuels.	#262 + #279 + #280
SE410_Gross farm income	€	Output - Intermediate consumption + Balance current subsidies & Taxes.	SE131 - SE275 + SE600
SE420_Farm net income	€	FNI: Remuneration to fixed factors of production of the farm (work, land and capital) and remuneration to the entrepreneurs risks (loss/profit) in the accounting year.	SE415 - SE365 + SE405
SE430_Farm net income/FWU	€	Farm net Income expressed per family labor unit. Takes into account differences in the family labor force to be remunerated per holding. It is calculated only for the farms with family labor.	SE420 / SE015
SE485_Total liabilities	€	Value at closing valuation of total of (long- , medium- or short-term) loans still to be repaid.	#394
SE605_Total subsidies excluding on investments	€	Subsidies on current operations linked to production (not investments). Payments for cessation of farming activities are therefore not included. Entry in the accounts is generally on the basis of entitlement and not receipt of payment, with a view to obtain coherent results (production/costs/subsidies) for a given accounting year.	SE610 + SE615 + SE650 + SE699 + SE624 + SE625 + SE626 + SE630
SE621_Environmental subsidies	€	Environmental subsidies. Including part of the measures of the article 69 of Regulation 1782/2003.	J800(2)+ J810(2)

Source: FADN, 2012

Annex 14: Calculations manure exported out of typical farms in Winterswijk

Collected data on manure exportation are lacking. Therefore, a calculation has been made by Hein Korevaar to approximate manure surpluses in three typical farms of Winterswijk based on data from CBS.

Typical dairy farm

Average stocking rate:

- 2.0 LU/ha

Percentage of permanent grassland

- 80%

Roughage self-sufficiency

- Roughage production in Winterswijk
    - Roughage intake of a typical dairy cows having a milk production > 8000 kg/yr : Ca. 15 kg DM good roughage per cow and per day
    - Production forage maize: 46.4 tonnes product, with ca. 33% dry matter -→ 15.0 ton DM/ha
    - Roughage production silage : 5.0 ton DM/ha
    - Hay: 0.2 T DM/ha
- Roughage production in a typical farm of 57 ha of UAA including:
    - 40 ha of grassland : Roughage produced in a typical farm = 40 * 5.0 = 200 T DM / TF
    - 17 ha maize : maize produced in a typical farm = 17 * 15.0 = 255 T DM / TF
    - Total roughage available in a typical farm= 455 T DM / TF
- Total LU per typical farm : 90 dairy cows and 66 young stock
    - LU of young stock: 66 * 0.6 = 40 LUs
    - LU of cows: 90 * 1 = 90 LUs
    - Total LUs: 90 + 40 = 130 LUs/TF
- Roughage intake of a typical herd (herd in a typical farm)
    - Herd consumption during winter: 130 * 15 * 182 days = 355 T DM/winter
    - Herd consumption during summer: 90 * 5 * 183 days = 82 T DM/summer
    - Total consumption: 355 + 82 = 437 T DM/year/TF

- Self-sufficient for roughage
    - Extra roughage in a typical farm: 455 – 437 = 18 T DM/year/TF

- Considering wastes we say the farm is self-sufficient in roughage

Nitrogen and Phosphorus production in a typical farm

	N	N-forfait	N-total	P2O5-forfait	P2O5 total
Dairy cow with > 8000 kg milk/yr	90	112.5	10125	42.9	3861
Young stock <1 yr	36	32.8	1181	9.3	334.8
Young stock >1 yr	30	70.2	2106	24.1	723
Total			13412		4919

Allowed application rates (Fertilization practices)

	Surfaces in a typical farm (ha)	N	Total	P	Total
Grassland	40	250	10000	95	3800
Maize land	17	170	2890	80	1360
Total	57		12890		5160

Nitrogen and Phosphorus balances

- Nitrogen: surplus:13412 - 12890 = 522 kg N (4% of total production)
- Phosphorus: some space: 4919 - 5160 = -241kg P2O5 (cannot be used due to N surplus)

Typical mixed farms

Average stocking rate Winterswijk

- 2009 2.02 LU/ha
- 2010 2.0 LU/ha

Percentage permanent grassland

- 80%

Roughage self-sufficiency

- Roughage intake of dairy cows (with milk production > 8000 kg/yr)
  - Ca. 15 kg DM good roughage per cow per day
- Production forage maize
  - 46.4 tonnes product, with ca. 33% dry matter -→ 15.0 ton DM/ha
- Roughage production silage
  - Roughage production silage : 5.0 ton DM/ha
  - Hay: 0.2 ton DM/ha
- Typical farm 57 ha 40 ha grassland

- 40 ha of grassland : Roughage produced in a typical farm = 40 * 5.0 = 200 T DM / TF
- 17 ha maize : maize produced in a typical farm = 17 * 15.0 = 255 T DM / TF
- Total roughage available in a typical farm= 455 T DM / TF

- Total LU per typical mixed farm (90 dairy cows and 66 young stock)
  - 66 * 0.6 = 40
  - Total LUs = 40 + 90 = 130
- Roughage intake
  - Winter 130 * 15 * 182 days ----→ 355 tonnes DM
  - Summer 90 * 5 * 183 days -----→ 82
  - Total consumption 437 tonnes DM

Nutrient balances

- Nitrogen and Phosphorus production in a typical farm

	N	N-forfait	N-total	P2O5-forfait	P2O5 total
Dairy cow with > 8000 kg milk/yr	65	112.5	7312	42.9	2788
Young stock <1 yr	24	32.8	787	9.3	223
Young stock >1 yr	18	70.2	1264	24.1	434
Total			9363		3445

- Allowed application rates (Fertilization practices)

	Surfaces in a typical farm (ha)	N	Total	P	Total
Grassland	30	170*	5100	95	2850
Arable and maize land	50	170	8500	80	4000
Total	80		13600		6850

*no derogation allowed, less than 70% grassland.

- Nitrogen and Phosphorus balances
  - Nitrogen: space for slurry import at the farm level: 13600 - 9363 = 4237 kg N
  - Phosphorus: some space: 6850 - 3445 = 3405 kg P

Arable farms

	Surfaces in a typical farm (ha)	N	Total	P	Total
Arable crops	80	170	13600	80	6400
Total	80		13600		6400

- Nitrogen and Phosphorus balances
  - Nitrogen: space for slurry import at the farm level:13600 kg N (1915 tonnes pig slurry)
  - Phosphorus: space for slurry import at the farm level:6400 kg P (1390 tonnes pig slurry)

Annex 15: Extension of the EU farm typology with an intensity and land use dimension

“The typology is based on a combination of two different dimensions, a land use and an intensity dimension. The definitions of the two dimensions can be found in the table below. Types are suggested based on the proportion of agricultural land in permanent, temporary and rough grassland and the type of cropping mix on arable land. The intensity dimension is based on the output of agricultural products in economic terms”(Andersen et al., 2007, pp. 355).

Intensity dimension	
Low-intensity	Total output[a] per ha<500 euro
Medium-intensity	Total output per ha >=500 and <3000 euro
High-intensity	Total output per ha >=3000 euro
Land use dimension	
1. Land independent	Agricultural area (UAA) ¼ 0 or livestock units per haX5
2. Horticultural	Not 1 and X50% of UAA in horticultural crops
3. Permanent crops	Not 1 or 2 and X50% of UAA in permanent crops
4. Temporary grass	Not 1, 2 or 3 and X50% of UAA in grassland and X50% of grassland in temporary grass
5. Permanent grass	Not 1, 2 or 3 and X50% of UAA in grassland and o50% of grassland in temporary grassland)
6. Fallow land	Not 1, 2, 3, 4 or 5 and X12.5% of UAA in fallow)
7. Cereal	Not 1, 2, 3, 4, 5 or 6 and X50% of UAA in cereals)
8. Mixed crops	Not 1, 2, 3, 4, 5, 6 or 7 and o25% of arable crops in specialized crops
9. Specialized crops	Not 1, 2, 3, 4, 5, 6, 7 or 8.

Source: Andersen et al., 2007