Risque, temps et adoption des cultures pérennes énergétiques : exemple du cas français

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RISQUE, TEMPS ET ADOPTION DES CULTURES PERENNES ENERGETIQUES :

EXEMPLE DU CAS FRANCAIS

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RISQUE, TEMPS ET ADOPTION DES CULTURES PERENNES ENERGETIQUES : EXEMPLE DU CAS FRANCAIS

RISK, TIME AND ADOPTION OF PERENNIAL ENERGY CROPS: INSIGHTS FROM THE FRENCH SETTING

Géraldine Bocquého

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Communications et publications issues de la thèse

Publications dans des revues à comité de lecture

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– 2011, August 30-Sept 2, *European Association of Agricultural Economists (EAAE), triennal congress*, Zurich, Switzerland (**Chapitre 3**)

– 2011, May 19-21, *French Association of Experimental Economists (ASFEE), annual meeting*, Schœlcher, Martinique, France (**Chapitre 3**)

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Communications dans des conférences nationales et séminaires

- 2011, December 12 *INRA, internal seminar, Public Economics Research Unit*, Grignon, France (**Chapitre 4**)
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- 2010, March 16, *INRA, 'Biofuel' seminar, Economics Department*, Paris, France (**Chapitre 1**)
- 2009, November 16-17, *INRA, 'Economics of Agricultural Production' seminar, Economics Department*, Rennes, France (**Chapitre 1**)
- 2009, October 1-2, *INRA, 'Young Researchers' seminar, Economics Department*, Montpellier, France (**Chapitre 1**)

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Introduction générale

Après le défi productiviste des années 1950 à 1980, l'agriculture moderne est aujourd'hui confrontée à de nouvelles attentes de la société : assurer une production alimentaire de qualité, respecter l'environnement et, en même temps, fournir de la biomasse pour des usages non-alimentaires. Ce dernier volet a reçu dernièrement une attention particulière en raison de la contribution des bioproduits à la lutte contre le réchauffement climatique. En effet, au cours de leur cycle de vie, les produits issus de végétaux sont susceptibles d'afficher un meilleur bilan gaz à effet de serre que ceux issus de l'industrie pétro-chimique. Même si les cultures non-alimentaires ont une longue histoire dans l'agriculture des pays développés (fibres textiles, huiles et résines à usage industriel, produits pharmaceutiques...), leur promotion était surtout justifiée par des considérations économiques sectorielles (nouveaux débouchés pour les agriculteurs et innovations agro-industrielles).

L'attention renouvelée portée aux bioproduits s'est concentrée ces dernières années sur les bioénergies, en raison des volumes et des valeurs en jeu considérables. Au-delà des motivations environnementales, l'épuisement inéluctable des ressources fossiles appelle aussi les Etats occidentaux à réduire leur dépendance en développant des sources d'énergie alternatives.

Les énergies renouvelables font ainsi l'objet d'un soutien politique important, se traduisant dans le cas de l'Union Européenne par des objectifs à court terme ambitieux et contraignants : 20% d'énergie d'origine renouvelable dans la consommation totale d'énergie d'ici 2020, et 10% dans le secteur des transports (Directive Energies Renouvelables EU 2009/28/EC).[1] Pour atteindre ces objectifs, notamment ceux relatifs aux transports qui dépendent largement de la disponibilité de carburants liquides, le recours aux biocarburants est clairement encouragé, en particulier ceux dits de deuxième génération.[2] Les biocarburants de première génération

1. Disponible à : http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:140:0016:0062:fr:PDF.
2. Les transports sont à l'origine de près d'un quart des émissions françaises et européennes de gaz à effet de serre.

sont ceux produits à partir des molécules de réserve des végétaux, typiquement les huiles et sucres issus de plantes alimentaires telles que le colza, la betterave, le maïs. Les biocarburants de deuxième génération proviennent, eux, de la transformation des molécules de structure que sont la lignine et la cellulose, présentes dans tous les organes du végétal. Les sources possibles de biomasse sont variées : résidus agricoles et forestiers (paille de céréales, bagasse de canne à sucre, effluents d'élevage, rémanents forestiers), déchets organiques (fraction organique des déchets ménagers, boues de stations d'épuration, effluents des industries agro-alimentaires), co-produits des industries du bois (sciures, liqueur noire), bois, plantes énérgétiques dédiées annuelles (sorgho fibre, triticale plante entière) ou pérennes (luzerne, miscanthus, panic érigé, taillis forestiers à courte rotation).

Pour limiter un certain nombre d'effets pervers des biocarburants, l'Union Européenne a mis en place un système de certification reposant sur quatre critères de durabilité. Ces critères portent sur (i) la réduction des émissions de gaz à effet de serre [3], (ii) les terres de grande valeur en termes de biodiversité, (iii) les terres présentant un stock important de carbone et (iv) les bonnes pratiques agro-environnementales (Directive Energies Renouvelables EU 2009/28/EC).

Les avantages de la seconde génération de biocarburants sur la première génération en termes de durabilité sont clairs. D'une part, ils exercent une concurrence plus faible avec les autres usages des ressources en terre (notamment les usages alimentaires). Ils ont donc potentiellement un moindre effet déstabilisateur sur les prix des matières premières alimentaires et forestières. En effet, les résidus et déchets sont les sous-produits d'une activité principale non énergétique dont les ressources ne sont pas ou peu modifiées. Dans le cas des plantes dédiées, l'ensemble du végétal est transformé ce qui permet une importante quantité d'énergie produite par unité de surface. [4] De plus, pour certains de ces végétaux, le rendement est maintenu même dans des conditions pédo-climatiques défavorables (miscanthus, panic érigé, taillis forestiers) ce qui permet l'exploitation de terres *marginales* peu adaptées à la production alimentaire.

D'autre part, les bilans énergétiques et environnementaux sont nettement améliorés. En effet, les résidus et déchets sont considérés comme des matériaux ne dégageant aucune émission de gaz à effet de serre au cours du cycle de vie jusqu'à leur collecte (European Union, 2009, , Annexe

3. Un gain de 35% par rapport aux références fossiles est exigé. A partir de 2017, ce taux sera porté à 50% et à partir de 2018 à 60% pour les nouvelles unités de production. Le calcul des émisions évitées doit prendre en compte les changements directs et indirects d'usage des sols.

4. On connaît mal les effets de la concurrence des plantes dédiées avec une autre ressource limitée, l'eau. Dans le cas du miscanthus, elle pourrait être significative dans les régions où l'eau est particulièrement rare.

V). Les plantes dédiées pérennes (luzerne, miscanthus, panic érigé, taillis), elles, présentent des bilans favorables en raison de leur faibles exigences en intrants et opérations culturales. Par ailleurs, grâce à une couverture hivernale du sol et au développement de sytèmes racinaires étendus, les cultures dédiées pérennes procurent certains services écosystémiques comme le stockage du carbone atmosphérique, le maintien de la structure du sol, la protection de la biodiversité. Les taillis de saule sont aussi reconnus pour leur pouvoir dépolluant sur les eaux et les sols, un phénomène connu sous le nom de phytoremédiation (Witters et al., 2012; Rosenqvist and Dawson, 2005).

Si la deuxième génération de biocarburants surpasse la première génération sur le plan de la durabilité, leur développement à l'échelle industrielle fait face à des obstacles techniques et économiques majeurs. Ils font en effet appel à des technologies plus sophistiquées que la première génération (voir Figure 1), qui sont encore au stade du développement expérimental.[5] Un rapport récent a évalué que les coûts de production des biocarburants de deuxième génération étaient compris entre 0,80 et 1,00 $ par litre équivalent essence dans le cas de la voie de transformation biochimique (éthanol lignocellulosique) et entre 1,00 et 1,20 $ par litre équivalent diesel dans le cas de la voie thermochimique (BtL) (International Energy Agency, 2008). Ces valeurs sont équivalentes au prix de gros des carburants fossiles lorsque le pétrole Brent est au-dessus de 100 $ le baril (essence) et au-dessus de 130 $ par baril (diesel). Etant donné la volatilité des cours actuels du pétrole, et leur tendance haussière[6], il est donc relativement risqué pour des énergéticiens d'investir dans la seconde génération de biocarburants. La transformation est le principal poste de coûts des biocarburants de deuxième génération : elle représente environ 50% à 70% des coûts de production totaux (Carriquiry et al., 2011). Cependant, les technologies de transformation utilisées étant récentes, il existe un potentiel important de réduction des coûts et d'optimisation du rendement énergétique. Ceci est particulièrement vrai pour la voie biochimique dont le procédé de tranformation, basé sur l'hydrolyse enzymatique de la cellulose, est lui-même immature. Le procédé de la voie thermochimique est basé sur la réaction de Fischer-Tropsch, largement exploitée et développée depuis la Seconde Guerre Mondiale pour produire du pétrole

5. Il existe également des recherches pour développer des procédés dits de troisième et quatrième génération à partir d'algues et de micro-organismes génétiquement modifiés respectivement.

6. Sur la période 2005–2011, le baril de Brent a dépassé sur le marché européen le prix de 100 $ le baril 1 jour sur 5, et sur la période 2000–2011, 1 jour sur 8 seulement (Source : calculs de l'auteur à partir des données de l'EIA (U.S. Energy Information Administration), consultables à : http://205.254.135.7/dnav/pet/hist/LeafHandler.ashx?n=PET&s=RBRTE&f=D).

à partir de charbon ou de gaz. C'est la qualité de la biomasse (homogénéité, pureté, taux d'humidité) et son conditionnement qui est problématique dans cette voie (International Energy Agency, 2008).

Il existe également un potentiel important de réduction des coûts de matière première par l'optimisation de la chaîne d'approvisionnement. Les coûts de collecte et de stockage sont en effet critiques à cause de la faible densité énergétique de la biomasse lignocellulosique et de son éparpillement géographique dans le cas des résidus agricoles et forestiers. Le stockage est aussi une étape logistique clé à cause de son impact important sur la qualité de la biomasse et sa disponibilité tout au long de l'année pour les transformateurs. Les techniques de récolte peuvent également être améliorées.

Enfin, la recherche agronomique et la sélection génétique concernant les cultures dédiées pérennes en sont à leur début, et on peut raisonnablement en attendre des améliorations significatives en termes de rendement, qualité, adaptation aux milieux pédo-climatiques difficiles et besoins en eau (Smeets et al., 2007). On estime qu'en 2030, l'éthanol lignocellulosique pourrait être compétitif avec un pétrole à 70 $ le baril, et le biodiesel avec un pétrole à 80 $ le baril (International Energy Agency, 2008).

Par comparaison, le potentiel de réduction des coûts de production des biocarburants de première génération est très faible. Le coût de la matière première représente en effet de 55% à 70% des coûts totaux et suit une tendance haussière depuis quelques années. En 2006 et 2007, les coûts de production nets[7] de l'éthanol de betterave européen étaient estimés à un peu moins de 0,80 $ par litre équivalent essence alors que le prix net de l'essence était d'environ 0,50 $ par litre. Sur la même période, ceux de l'éthanol de blé européen sont passés d'un peu moins de 1,00 $ à environ 1,30 $ par litre équivalent essence. Le biodiesel de colza affiche des coûts de production encore plus élevés, 1,20 $ par litre équivalent essence en 2006 et presque 1,80 $ en 2007 (International Energy Agency, 2008). En fait, à l'exception de l'éthanol de canne brésilien, les biocarburants de première génération ne sont pas compétitifs sans subventions publiques. Dans l'avenir, les prix agricoles sont peu susceptibles de diminuer de manière significative, et le renchérissement probable du prix de l'énergie sera sûrement insuffisant pour combler la différence de compétitivité. Par ailleurs, des sauts technologiques dans le procédé de transformation de première génération, optimisé depuis des décennies, ne sont pas attendus.

7. Déduction faite de la valeur des co-produits pour l'alimentation animale par exemple.

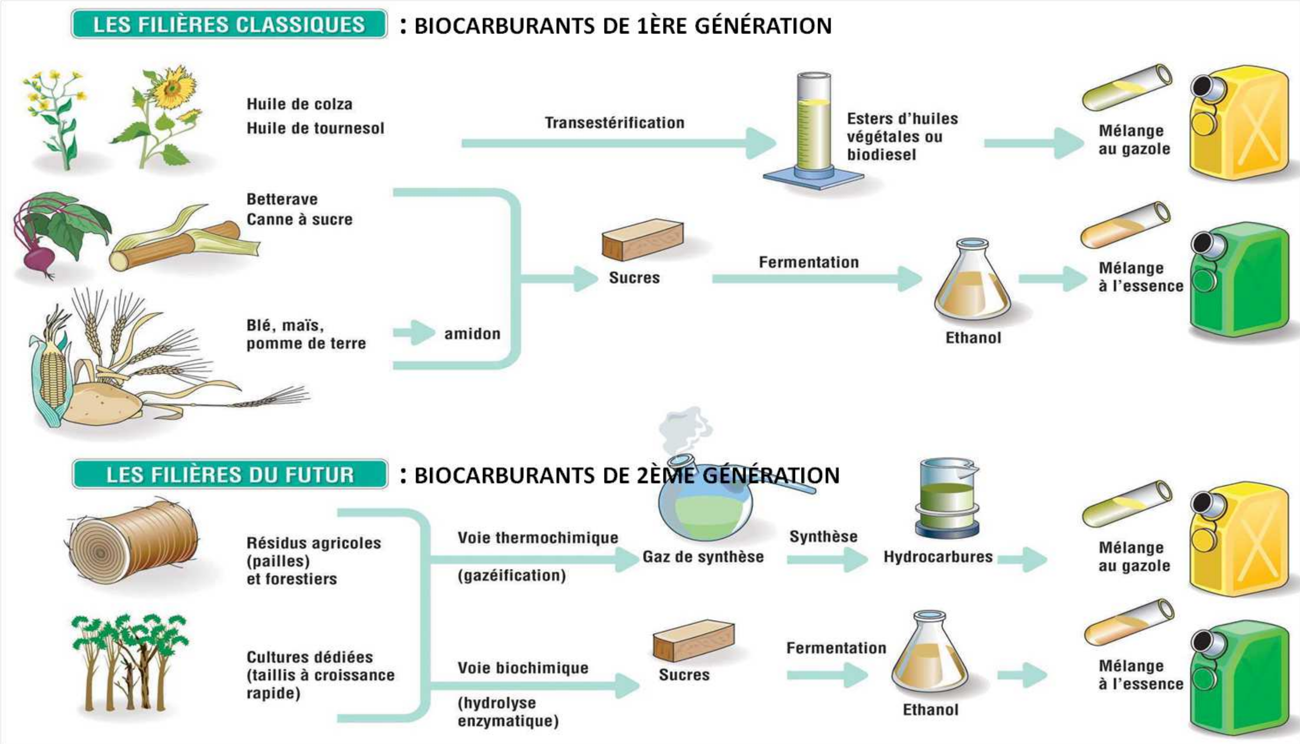
Pour accompagner l'investissement privé dans la deuxième génération de biocarburants, et accélérer l'émergence d'une filière française, les pouvoirs publics français ont participé ces dernières années à plusieurs importants programmes de recherche et développement. La voie biochimique fait notamment l'objet du programme intégré FUTUROL visant à développer sur dix ans une filière française. Initié en 2008 et doté d'un budget de plus de 75 millions d'euros, ce projet est financé à 40% par des fonds publics (OSEO Innovation) et associe différents partenaires de la recherche (ARD, INRA, Lesaffre, IFP [8]) de l'industrie (coopérative agricole Champagne Céréales, Confédération Générale des planteurs de Betterav, pétrolier Total, sucrier Téréos, forestier Office National des Forêts), et de la finance (Unigrains, Crédit Agricole). Le projet comporte deux grands volets. Le premier concerne la mise au point et la validation de la technologie de transformation, depuis le prétraitement de la biomasse jusqu'à la gestion des coproduits et rejets. Ce volet prévoit la construction d'une unité prototype pour 2015 (100 tonnes de matière sèche traitée par jour et 3,5 millions de litres de bioéthanol par an), étendu à une échelle industrielle en 2016 (180 millions de litres de bioéthanol par an). Le second volet concerne la ressource, les conditions de sa mobilisation et son bilan environnemental. C'est dans ce deuxième volet du projet FUTUROL que s'inscit cette thèse.

Le développement des technologies de deuxième génération à l'échelle industrielle posera de façon accrue la question du volume de biomasse disponible et de son coût. Le principal inconvénient des ressources de type résidus est leur éparpillement géographique et leur difficulté d'accès dans le cas des résidus forestiers (contraintes topographiques, manque d'infrastructures). Les déchets et co-produits issus d'un processus de transformation sont plus concentrés, mais, comme dans le cas des résidus, il existe des conflits d'usage pour certains d'entre eux (paille utilisée comme source de matière organique dans les sols et pour l'alimentation des animaux d'élevage, sciures de bois utilisées dans l'industrie papetière ou en chaufferie). Les co-produits importés tels que la bagasse sont, eux, pénalisés du point de vue des critère de durabilité en raison du poids du transport dans leur bilan environnemental.

La problématique de la ressource bois est quelque peu différente. Sa disponibilité dépend du consentement à produire de propriétaires forestiers privés qui pour beaucoup d'entre eux voient la forêt comme un patrimoine plutôt qu'un écosystème productif [9].

8. Agro-industries Recherche et Développement, Institut national de la Recherche Agronomique, Lesaffre, Institut Français du Pétrole

9. En France, les trois-quarts des surfaces forestières appartiennent à des propriétaires privés. Seulement 60%



Source : Institut Français du Pétrole

Figure 1 – Technologies de transformation de la biomasse en biocarburants

Il est donc probable que dans certaines régions le recours à des cultures énérgétiques dédiées soit nécessaire pour approvisionner en totalité ou en partie les unités de biocarburants à partir d'un rayon de collecte donné. On estime qu'un rayon de collecte raisonnable pour une unité moyenne produisant 25 à 50 millions de litres de carburant par an et utilisant 60 000 à 120 000 tonnes de matière sèche par an serait de 20 km (International Energy Agency, 2008). Par rapport aux autres cultures candidates pour la fourniture de biomasse, les herbacées pérennes come le miscanthus et le panic érigé présentent l'avantage d'être très performantes du point de vue énergétique et environnemental (Sultana and Kumar, 2012). En effet, elles ont un rendement élevé malgré une très grande sobriété en intrants et opérations culturales (Lewandowski et al., 2003; St Clair et al., 2008), un temps d'entrée en production relativement court (par rapport aux taillis forestiers), et réalisent une couverture du sol en hiver (Hansen et al., 2004; Bellamy et al., 2009). Comme dans le cas du bois, la disponibilité des plantes dédiées pour la production de biocarburants dépend du consentement des agriculteurs à les produire.

L'objectif de cette thèse est d'identifier les déterminants de l'adoption des cultures pérennes énergétiques par les agriculteurs. Nous avons pris l'exemple de deux herbécées pérennes, le

de la croissance annuelle de la forêt est récoltée.

miscanthus (*Miscanthus giganteus*) et le panic érigé (*Panicum virgatum*), dans le contexte français. Les herbacées pérennes présentent plusieurs attributs originaux par rapport aux productions auxquelles les agriculteurs français sont habitués. Premièrement, ce sont des espèces nouvelles, commercialisées sur un marché de la biomasse-énergie inhabituel pour les agriculteurs. Actuellement, et en attendant l'arrivée à maturité des technologies de biocarburants de deuxième génération, elles sont utilisées comme combustible pour produire de l'électricité ou de la chaleur. [10] Les herbacées pérennes correspondent donc bien à la définition de l'innovation proposée par Schumpeter (1934) : « *La fabrication de nouveaux biens (...), l'introduction de nouvelles méthodes de production (...), l'ouverture de nouveaux débouchés (...), l'utilisation de nouvelles matières premières (...) et la réalisation d'une nouvelle organisation du travail* ». Comme il est généralement admis pour les innovations agricoles, le manque de connaissances à leur sujet en termes de performances et savoir-faire est suceptible de générer des risques supplementaires pour les agriculteurs. Deuxièmement, le marché sur lequel elles sont commercialisées est local et émergent, et offre donc encore peu de débouchés. Par conséquent, le risque prix est particulièrement fort sur ces cultures. Troisièmement, la plantation des herbacées pérennes demande un investissement important alors que l'entrée en production intervient deux ou trois ans après. L'amortissement des frais d'implantation requiert plusieurs années et le calcul de la rentabilité s'effectue sur 10 à 15 ans. Ceci a plusieurs conséquences. D'abord, le revenu (relatif) qu'un agriculteur peut attendre des herbacées pérennes est particulièrement aléatoire car le contexte économique et législatif est susceptible de beaucoup évoluer à partir de la décision d'implantation. En particulier, l'évolution de la demande et de l'offre de biomasse, et donc le prix de l'output, sont difficiles à prévoir. L'évolution des prix des outputs des usages concurrents de la parcelle est aussi une source de risque. Ensuite, des ressources financières doivent être disponibles et leur immobilisation sur plusieurs années a un coût. Par ailleurs, comme l'investissement s'amortit sur plusieurs années, arracher les cultures pérennes avant la fin du cycle productif et allouer la terre à une activité plus rentable est très coûteux, surtout au début du cycle. Ce manque de flexibilité est d'autant plus regrettable qu'il concerne une culture nouvelle dont les agriculteurs connaissent mal l'adaptation à leurs propres conditions pédo-climatiques. Enfin, en raison du montant important de l'investissement initial, un accident de production ou de commercialisation (absence de levée, absence de débouchés par exemple) qui annulerait les

10. Les premières parcelles commerciales de miscanthus et panic érigé datent de 2005.

revenus de plusieurs années serait extrêmement coûteux. Ces trois attributs, innovation, marché émergent, cycle de production long, sont potentiellement très dissuasifs pour des agriculteurs candidats à l'adoption. Pourtant, on observe en France depuis 2005 une augmentation rapide des surfaces dédiées aux cultures pérennes énergétiques, dans certaines régions et chez certains agriculteurs. Mieux comprendre les déterminants de l'adoption actuelle doit pouvoir éclairer les conditions d'un développement futur de ces cultures.

En raison des spécificités des herbacées pérennes évoquées précédemment, nous nous sommes concentrée sur les déterminants liés à l'effet du risque et du temps sur le processus d'adoption. La problématique de recherche se résume à deux questions :

1. Quelles sont les motivations des agriculteurs pour adopter les herbacées pérennes énergétiques ?
2. Quel rôle joue l'hétérogénéité des agriculteurs dans l'adoption, en particulier les différences dans leurs préférences par rapport au risque et au temps ?

Historiquement [11], l'adoption des innovations d'abord été analysée empiriquement, en termes de *diffusion*. Cela signifie que les chercheurs se sont intéressés à la propagation des innovations au cours du temps au sein d'une population d'agents économiques, c'est-à-dire à une mesure agrégée de l'adoption. En agriculture, les premiers travaux ont été menés par des sociologues qui ont observé que la diffusion d'une innovation correspondait à une fonction sigmoïde du temps. Trois périodes peuvent être distinguées : une période initiale au cours de laquelle peu d'agriculteurs adoptent l'innovation, une période de décollage caractérisée par une adoption massive, puis une période de saturation au cours de laquelle le nombre de nouveaux adoptants est à nouveau faible, le nombre d'adoptant total tendant vers un maximum. Rogers (1962) proposa une classification des individus en cinq catégories selon la rapidité avec laquelle ils adoptaient une innovation donnée : innovateurs, adopteurs précoces, majorité précoce, majorité tardive, et retardataires. [12] Les travaux fondateurs de Griliches (1957) sur la diffusion du maïs hybride aux Etats-unis dans différentes régions ont permis de montrer que les différences de profit entre nouvelle et ancienne technologie, et les variables économiques en général (densité des débouchés, coût des semences, coûts de commercialisation) avaient un effet fort sur les paramètres de la courbe en S.

11. Voir Sunding and Zilberman (2001), Feder et al. (1985), et Feder and Umali (1993) pour une revue complète de la littérature sur l'adoption d'innovations en agriculture.
12. En anglais, *innovators*, *early adopters*, *early majority*, *late majority*, et *laggards*.

Plusieurs études théoriques ont parallèlement émergé pour expliquer cette courbe de diffusion en S. Un premier groupe d'auteurs a considéré que la communication étaient à la base du processus de diffusion. Mansfield (1963) a par exemple proposé un modèle dans lequel le taux de diffusion à l'instant t dépend de la diffusion déjà réalisée à t. Dans ce modèle, l'imitation rendue possible par le contact entre agents, est vue comme le moteur de la diffusion.

Ce type d'approche a été ensuite critiquée en raison de l'absence de fondement microéconomique solide au comportement des agents. Ces critiques ont donné lieu à un nouvel ensemble de recherches dans lesquelles les agriculteurs sont hétérogènes et la maximisation du profit individuel est le moteur de l'adoption. Certains modèles ont mis en évidence le fait que l'hétérogénité des agriculteurs établissaient des seuils en-dessous desquels il n'était pas économiquement rentable d'adopter une innovation. Par exemple, David (1969) a montré que l'adoption de la moissonneuse au XIXe siècle aux Etats-Unis n'était pas rentable en-dessous d'une certaine taille d'exploitation. Caswell and Zilberman (1986) ont montré que l'adoption de techniques modernes d'irrigation concernait les terres de moindre qualité et pour lesquelles les nappes phréatiques était profondes (et donc l'accès à cette eau coûteux). D'autres auteurs ont étendu ce type de modèle aux univers risqués. En raison du manque de connaissances de l'agriculteur sur l'innovation, celle-ci est généralement vue comme plus risquée que les activités agricoles traditionnelles. Ce risque perçu peut se superposer aux risques objectifs inhérents à l'activité agricole (Feder, 1980; Just and Zilberman, 1983). Enfin, les modèles dynamiques mettent l'accent sur l'évolution des caractéristiques de l'innovation au cours du temps. D'une part, l'apprentissage par l'acquisition d'expérience et d'information explique que le risque lié à la nouvelle technologie tende à se réduire au cours du temps (*learning-by-using*) (Feder and O'Mara, 1981; Abadi Ghadim and Pannell, 1999; Leathers and Smale, 1991; Besley and Case, 1993; Tsur et al., 1990). D'autre part, l'apprentissage peut aussi rendre les agriculteurs plus efficaces dans l'utilisation de la nouvelle technologie (*learning-by-doing*) (Abadi Ghadim and Pannell, 1999). Par ailleurs, la généralisation d'une innovation visant à augmenter la productivité (et donc l'offre) d'un produit tend à diminuer le prix de ce-dernier. Par conséquent, seuls les adoptants précoces profitent à long terme de l'adoption de la dite innovation (Zilberman, 1984; Cochrane, 1979).

Ces modèles de décision rationnelle ont orienté les études empiriques vers l'analyse des processus d'*adoption individuelle* plutôt que de diffusion, et des facteurs à l'origine des différences dans le processus d'adoption. Une vaste littérature a alors mis en évidence un très grand nombre de déterminants pour expliquer l'adoption d'innovations agricoles. L'ensemble de ces travaux permet d'identifier les catégories clés suivantes : taille de l'exploitation, risque et incertitude (et accès à l'information), capital humain, disponibilité de la main d'œuvre, disponibilité du crédit, tenure de la terre, disponibilité des inputs complémentaires, éléments dynamiques (apprentissage et prix des outputs) (Feder et al., 1985). Les déterminants sont suceptibles d'évoluer suivant la phase du processus de diffusion considérée, beaucoup d'entre eux n'étant plus significatifs dans la dernière phase (Feder and Umali, 1993).

Cette thèse se place dans ce courant de la littérature économique qui s'intéresse aux déterminants individuels de l'adoption. A partir du problème empirique original des herbacées pérennes énérgétiques, nous nous intéressons plus particulièrement au lien entre adoption d'innovation, *risque* et *temps*. Malgré une littérature abondante, il existe peu d'études empiriques traitant convenablement des facteurs liés au risque en raison des difficultés à les observer et mesurer avec précision (Feder et al., 1985). Ceci est vrai pour les distributions de probabilité mais aussi pour les préférences individuelles.

La mesure des préférences par rapport au risque (ou au temps) en économie de la production fait appel à trois grands types de méthodes. Les méthodes de *préférences révélées* correspondent à des estimations économétriques basées sur l'observation des décisions des agents économiques (dans le cas des agriculteurs, leurs décisions de production ou leurs choix d'investissement) (Antle, 1987, 1989; Chavas and Holt, 1996; Pope and Just, 1991).[13] A condition de faire des hypothèses explicites sur la technologie de production utilisée, le risque supporté, et dans une certaine mesure sur la règle de décision des agents, la mise en relation des inputs choisis et des outputs obtenus permet de révéler les préférences des agents face au risque. En plus de reposer sur des hypothèses fortes, le principal inconvénient de cette approche est de risquer de confondre les préférences individuelles avec d'autres facteurs intervenant dans les choix de production, par exemple les contraintes de ressources (Just, 2003). De plus, cette méthode fournit une mesure agrégée des préférences pour un ensemble ou un sous-ensemble d'agents, et de fait ne rend pas totalement compte de leur hétérogénéité. Enfin, elle est exigeante en données, et nécessite de disposer d'un panel pour observer les réponses des individus à un changement de contexte.

Dans les méthodes de *préférences déclarées*, on demande directement aux agents de répondre

13. Voir Gardebroek (2006), Serra et al. (2008), ou Koundouri et al. (2009) pour des exemples récents.

àun questionnaire d'enquête spécialement formulé pour évaluer leur attitude vis-à-vis du risque. Les questions peuvent prendre la forme d'auto-évaluations dans lesquelles les agents notent eux-mêmes leur degré d'aversion au risque, ou reproduire artificiellement des situations impliquant des revenus plus ou moins risqués, entre lesquelles les agents doivent choisir ou pour lesquelles ils doivent donner une note, ou leur équivalent certain (Dillon and Scandizzo, 1978; Hardaker et al., 2004; Pennings and Garcia, 2001; Pennings and Smidts, 2003). Ces méthodes sont généralement conçues pour donner une valeur unique aux préférences, mais elles peuvent aussi expliciter leur structure, par rapport à la richesse des individus par exemple. L'inconvénient majeur des méthodes de préférences déclarées est l'incertitude du chercheur par rapport à l'implication des sujets dans leur réponse, engendrant un biais hypothétique potentiellement important et impossible à contrôler. Elles ont cependant l'intérêt d'autoriser une large gamme de questions et de contextualisations, et fournissent des mesures individuelles.

Comme les approches déclarées, les approches *expérimentales* sont des méthodes de mesure directes dans lesquelles les agents sont mis face à des situations de choix artificielles.[14] Elles s'en distinguent cependant de deux manières. Premièrement, elles prennent place dans un environnement contrôlé dans lequel seules les préférences par rapport au risque influencent les choix.[15] Le plus souvent, les alternatives correspondent à des loteries dont les probabilités et les montant en jeu sont variables. Deuxièmement, il existe un mécanisme de rémunération des agents qui dépend des choix qu'ils ont réalisé. Les choix ont donc des conséquences réelles, ce qui limite le biais hypothétique. Les méthodes expérimentales ont connu un grand succès depuis les travaux fondateurs de Binswanger (1980) sur l'aversion des agriculteurs en Inde. Des protocoles multiples et des techniques d'estimation sophistiquées ont ensuite été développées pour, à la fois, améliorer la précision des mesures, et tester la pertinence de théories de la décision concurrentes (Harless and Camerer, 1994; Hey and Orme, 1994; Loomes et al., 2002; Bruhin et al., 2010). Si la plupart des mesures réalisées ont concerné des populations d'étudiants en laboratoire, certains auteurs se sont intéressés à des populations économiquement significatives, comme par exemple la population danoise (Harrison et al., 2007). Quelques auteurs ont également suivi la voie de Binswanger et mis en place des expériences auprès des populations rurales pour

14. Voir Harrison and Rutström (2008) pour une synthèse des méthodes d'économie expérimentale pour la mesure des préférences par rapport au risque.

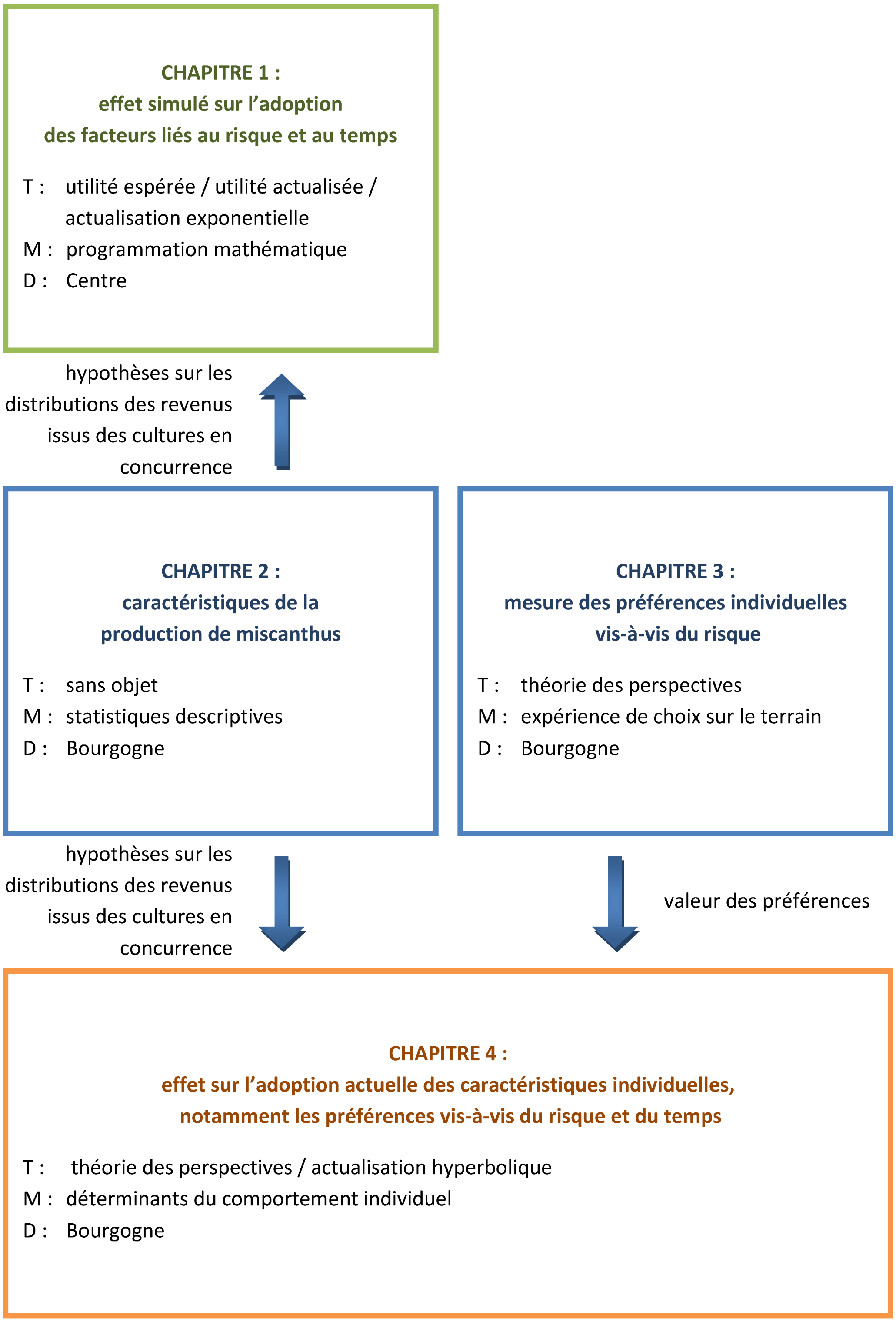
15. En réalité, il existe un gradient dans le niveau de contrôle qui est maximal pour les expériences de laboratoire (*lab experiments* en anglais) et généralement plus faible pour les expériences de terrain (*field experiments*) impliquant des populations non étudiantes.

mesurer leurs préférences par rapport au risque (Grisley and Kellog, 1987; Yesuf and Bluffstone, 2009; Harrison et al., 2010; Tanaka et al., 2010; Humphrey and Verschoor, 2004a) ou au temps (Duquette et al., 2011). Cependant, les préférences déclarées sont encore largement utilisées pour la facilité de leur mise en œuvre.

Pour éclairer le lien entre adoption de cultures pérennes énergétiques et préférences des agriculteurs par rapport au risque et au temps, nous avons pris le parti de minimiser le biais hypothétique en mettant en relation des données d'enquête sur le choix réel d'adoption et des données expérimentales sur les préférences individuelles.

La thèse comprend quatre chapitres correspondant à quatre articles de recherche. Le Chapitre 1 présente un travail de simulation de l'adoption, à l'aide d'un modèle normatif qui postule différents niveaux de préférences face au risque et au temps. Les données sont principalement issues d'une enquête préliminaire réalisée dans la région Centre (Bocquého, 2008). Dans les Chapitres 2 à 4, nous proposons les résultats d'une étude empirique de l'adoption en région Bourgogne. Après avoir décrit les caractéristiques de la production de miscanthus dans cette région (Chapitre 2), nous mesurons à partir d'un dispositif d'économie expérimentale les préférences face au risque des agriculteurs (Chapitre 3). Nous analysons ensuite le rôle de ces préférences dans l'adoption actuelle du miscanthus, parmi d'autres déterminants potentiels (Chapitre 4). La Figure 2 met en valeur les différences dans les approches et les données entre les quatre chapitres de la thèse, et les liens existant entre eux. Dans les lignes suivantes nous détaillons le contenu et les apports méthodologiques de chacun des chapitres.

Dans le Chapitre 1, nous évaluons l'impact du risque et du temps sur l'allocation optimale des ressources en terre dans une exploitation agricole. Les revenus issus des cultures en concurrence sont annuels ou pluriannuels. Nous prenons l'example du miscanthus et du panic érigé en région Centre. Nous comparons l'allocation optimale des terres obtenue avec quatre cadres d'analyse différents : analyse coût-bénéfice simple, utilité actualisée standard (Samuelson, 1937), utilité espérée standard (von Neumann and Morgenstern, 1947), et utilité espérée actualisée. De plus, nous évaluons la sensibilité des résultats aux préférences individuelles des agriculteurs d'une part, et aux profils des revenus attendus d'autre part. Dans le premier cas, nous faisons varier les préférences par rapport au risque, au temps, et aux fluctuations intertemporelles. Dans le second cas, nous considérons pour les revenus plusieurs niveaux de variabilité dans



Légende : T (cadre théorique), M (méthode), D (données)

FIGURE 2 – Structure de la thèse

l'instant (volatilité), dans le temps (fluctuations intertemporelles), et plusieurs horizons de planification (longueur du cycle de production). Ces dernières simulations permettent de mettre en évidence l'impact important sur l'allocation des terres des dispositifs de lissage que prévoient certains contrats de production, tels que prix garanti à long-terme et crédits de trésorerie. Sur le plan méthodologique, ce chapitre suggère que le modèle de l'utilité actualisée et l'aversion aux fluctuations intertemporelles, généralement réservés aux comportements de consommation, peuvent être pertinents pour expliquer l'adoption d'innovations pérennes qui demandent une trésorerie disponible pour investir au début du cycle de production.

Après avoir exploré dans le Chapitre 1 le rôle du risque, du temps, et de leur interaction dans la décision d'adopter une culture pérenne, nous nous sommes intéressée dans les Chapitres 3 et 4 au rôle des événements extrêmes et des points de référence dans la perception des distributions de revenus et le comportement face au risque.

En effet, en raison du montant de l'investissement initial pour planter les espèces pérennes, des événements comme l'échec de l'installation de la culture ou la faillite de la contrepartie du contrat de production ont potentiellement des effets extrêmement négatifs sur les revenus des agriculteurs. Les points de référence, eux, définissent la façon dont les agents classifient les revenus en gains ou pertes. Les agriculteurs qui font face au choix d'adopter une innovation ne sont pas tous dans la même situation initiale en termes de revenus, ou n'ont pas les mêmes aspirations quant aux revenus attendus. La classification des revenus issus de l'innovation en gains ou pertes est donc susceptibles d'être variable en fonction des points de référence des agriculteurs. Un même agriculteur pourrait également avoir plusieurs points de référence, par exemple, dans le cas d'une nouvelle culture, en fonction des performances des espèces remplacées. De nombreuses observations empiriques ont montré que les individus avaient tendance à se comporter différemment en univers risqué, selon que les revenus en jeu, d'une part, intégraient ou non des événements extrêmes, et, d'autre part, étaient perçus comme des gains ou des pertes. La théorie des perspectives (Kahneman and Tversky, 1979; Tversky and Kahneman, 1992) permet de rendre compte de ces deux aspects du comportement face au risque. Ce cadre d'analyse récent fait partie de la grande famille des *modèles de comportement*. Alliant formalisation mathématique et prise en compte des biais psychologiques, ils sont particulièrement appropriés pour décrire et prédire les décisions des individus, contrairement aux modèles standards à visée essentiellement normative. Si les préférences des agriculteurs par rapport au risque ont été abondamment décrites et mesurées dans le cadre standard de l'utilité espérée, il existe beaucoup moins de travaux traitant des préférences des agriculteurs dans le cadre de la théorie des perspectives, plus complexe, en particulier dans les pays développés. De plus, alors que les préférences standard sont souvent approximées avec des méthodes de préférences déclarées, il n'existe pas d'équivalent simple et suffisamment fiable pour les préférences telles que décrites par la théorie des perspectives. Dans notre analyse du lien entre adoption d'innovation et risque, il nous est donc apparu nécessaire d'effectuer un détour par la mesure explicite de ces préférences.

L'analyse empirique des Chapitres 3 et 4 s'appuie sur un échantillon d'agriculteurs de Bourgogne. Comme dans la région Centre, la diffusion des herbacées énergétiques y est particulièrement rapide, mais la Bourgogne présente l'avantage d'être plus diversifiée en termes de types d'exploitations et de conditions pédo-climatiques.

Dans le Chapitre 2, nous décrivons en détail les caractéristiques de la production de miscanthus en Bourgogne. Nous nous intéressons aux pratiques agronomiques des agriculteurs relativement au miscanthus, aux conditions économiques qui prévalent dans la région, et aux perceptions des agriculteurs vis-à-vis des effets du miscanthus sur leur exploitation. Les effets du miscanthus sur l'exposition au risque des agriculteurs sont particulièrement détaillés, et justifient les hypothèses des Chapitres 1 et 4 sur les distributions de revenus des cultures en concurrence.

Dans le Chapitre 3, nous mesurons les préférences des agriculteurs par rapport au risque dans le cadre de la théorie des perspectives. Nous les estimons à partir d'un protocole expérimental qui propose à 107 agriculteurs de choisir entre plusieurs situations stylisées plus ou moins risquées. Les situations sont hypothétiques mais l'expérience donne lieu à une rémunération qui dépend des choix réalisés. L'estimation des préférences fait appel à une méthode économétrique structurelle. Nous passons également en revue les principales implications des préférences des perspectives pour l'économie agricole. Ce chapitre à portée générale sur la question du risque en agriculture milite pour un plus grand recours à la théorie des perspectives pour expliquer les décisions individuelles.

Dans le Chapitre 4, nous quantifions l'effet des caractéristiques individuelles des agriculteurs et de leurs exploitations sur l'adoption réelle d'une culture pérenne en prenant comme cas d'étude le miscanthus en Bourgogne. En particulier, nous testons directement l'effet des préférences par rapport au risque en utilisant les mesures expérimentales du Chapitre 3, obtenues dans le cadre de la théorie des perspectives sur le même échantillon d'agriculteurs. Nous faisons varier le poids relatif des événements extrêmes et les points de référence en distinguant adoption sur terres marginales, aux conditions pédo-climatiques peu favorables, et adoption sur terres non marginales. Ce dernier chapitre enrichit la compréhension du lien entre adoption d'innovation et risque en agriculture, et constitue un exemple de l'utilisation des apports théoriques récents des modèles de comportement en mêlant données d'enquête et données expérimentales. Il éclaire également la question de la localisation de l'adoption qui est centrale dans l'évaluation de la durabilité des biocarburants de deuxième génération.

En conclusion, nous résumons les résultats obtenus et proposons des pistes pour prolonger nos recherches.

Chapter 1

The adoption of switchgrass and miscanthus by farmers: impact of liquidity constraints and risk preferences.

Lignocellulosic biomass is expected to become a key feedstock for renewable energy production. However, the potential supply strongly depends on farmers' willingness to grow the new perennial energy crops. Many economic assessments have been led at the farm level, all based on the standard net present value approach. This paper looks into the effect of farmers' liquidity constraints and risk preferences on switchgrass and miscanthus adoption by farmers. We study the problem of the land allocation between a traditional cropping system and an innovative one in a static framework, using four intertemporal choice models. We find that, in central France agronomic and economic conditions, switchgrass and miscanthus result to be less profitable in terms of annualised gross margin (426 €/ha/yr and 359 €/ha/yr respectively) than the usual rape/wheat/barley rotation. Nevertheless, they can be highly competitive as diversification crops when appropriate contracts are offered to farmers, despite the additional liquidity they require.

Keywords: farmers' behaviour, adoption intensity, herbaceous energy crops
JEL Codes: C61; Q12; Q16

1.1 Introduction

Many countries are now committed to fight global warming by reducing greenhouse gas emissions. Strict policies are being implemented in both Europe and the United States to favour renewable energy. For instance the European Union established '*mandatory national targets consistent with a 20% share of energy from renewable sources and a 10% share of energy from renewable sources in transport in Community energy consumption by 2020*' (European Union, 2009). The need for lignocellulosic biofuels to achieve this objective while fulfilling effective sustainability criteria is clearly indicated. Furthermore, lignocellulosic biomass combustion for power and heat production would be an other important process (Rowe et al., 2009). Among the likely lignocellulosic crops candidates for producing renewable energy, perennial switchgrass and miscanthus have been repeatedly cited as the most promising species for temperate areas when accounting for several environmental indicators. For example winter coverage has positive effects on soil quality (Hansen et al., 2004) and some animal biodiversity (Bellamy et al., 2009; Roth et al., 2005; Semere and Slater, 2007a,b). These herbaceous crops also provide high yields without requiring intensive management in terms of field operations and chemical inputs, which explains their good energy and greenhouse gas balance (Lewandowski et al., 2003; McLaughlin and Walsh, 1998; St Clair et al., 2008).

If many studies have approached the adoption of switchgrass and miscanthus from an environmental point of view, the questions about the economic efficiency of these crops and their probability of adoption by farmers are also addressed. As they are perennial, a time dimension is needed in the evaluations, as well as a representation of farmers' time preferences. The most common theoretical approach is the net present value (NPV) one, derived from the producer theory. It is largely dominant in general investment problems as well as in natural resource economics because of its simplicity. A single discount factor catches the decision-maker's preferences for the present over the future. Almost all of the numerous cost-benefit studies about perennial energy crops at the farm level are based on it. Most of them refer to willow short rotation coppices in either a European (Goor et al., 2000; Rosenqvist and Dawson, 2005; Stolarski et al., 2007; Toivonen and Tahvanainen, 1998; van den Broek et al., 1997) or an American setting (Nienow et al., 1999; Tharakan et al., 2005; Walsh, 1998). While several north American studies have also attempted to measure the economical interest of switchgrass production for farmers (Downing and Graham, 1996; Duffy and Nanhou, 2002; Fox et al., 1999; Khanna et al., 2008; Nelson et al., 2006), only a few have recently considered a European context (Lychnaras and Rozakis, 2006; Monti et al., 2007; Smeets et al., 2009). Economic valuations for miscanthus are scarcer (Deverell et al., 2009; Smeets et al., 2009; Styles et al., 2008). These studies provide very different results according to the cost items and areas considered, which makes them difficult to compare. They have two main drawbacks in common. They assume a deterministic context (or a risk-neutral farmer), using average values. Moreover, by aggregating the return pattern over the crop life-span into a timeless criterion, liquidity needs are ignored.

This paper looks into the *ex ante* effect of two factors on the potential extent of miscanthus and switchgrass adoption by farmers: liquidity constraints and risk preferences. Many studies have highlighted the central role played by uncertainty and risk aversion in agricultural innovation adoption (Flaten et al., 2005; Greiner et al., 2009; Koundouri et al., 2006; Marra et al., 2003; Serra et al., 2008). Financing constraints have been far less studied, at least in the economic context of developed countries. However, many studies show that some proxies of farmers' liquidity constraints constitute significant determinants of technology adoption, e.g., farm size, farmers' debt, extra agricultural income. The few adoption studies specifically dealing with perennial energy crops in developed countries confirm it (Bocquého, 2008; Jensen et al., 2007; Roos et al., 2000; Sherrington et al., 2008; Villamil et al., 2008). Thus, besides risk, financing constraints may be another important factor influencing the adoption of switchgrass and miscanthus. Indeed, these crops require a more or less lengthy establishment period before beginning to produce. During this phase, farmers have to invest in planting while no return is expected (Bocquého, 2008). In this context, assessing the economic conditions in which farmers would be willing to grow perennial herbaceous energy crops assuming a risk neutral behaviour and a perfect capital market could lead to conclusions that do not fully reflect reality.

In this paper, we study the general decision problem of the optimal land resource allocation of a farm between different cropping systems, in a static but multi-periodic framework. One of the crop is a perennial energy crop, switchgrass or miscanthus, whereas the other one is a traditional annual one. We compare four intertemporal choice models to separately and jointly assess the impact of liquidity constraints and risk aversion on the adoption intensity of switchgrass and miscanthus by farmers. Departing from the basic NPV cost-benefit analysis, we relax the assumption of the linearity of the decision-maker's utility and follow the discounted utility (DU) and expected utility (EU) theories. Thus, we provide a more complete economic assessment of perennial energy crops by fully taking into account farmers' risk, time and intertemporal preferences. It allows us to study the impact of different variant of supply contracts on farmers' decision.

This paper is organized as follows. Section 1.2 presents the theoretical models of adoption of a new crop. The empirical context and the parameterization are presented in Section 1.3. In this section the results of the simulations are also displayed, and a Monte Carlo analysis of the sensitivity to parameters is led. In Section 1.4, results are compared with other studies, followed by some concluding remarks.

1.2 New technology and intertemporal choices

The simple once-only decision problem we address aims to assess the relevancy for a farmer to grow miscanthus or switchgrass instead of conventional crops. We consider a representative farm with a homogenous arable area of L hectares which can be divided up by the farmer into a traditional cropping system and an innovative one. Consider a succession of crop years $1, \ldots, t, \ldots, T$ where T is the new technology pre-determined life-span. Crop prices and subsidies are assumed to be constant over years and rationally anticipated by farmers. On the contrary, yields and production costs can vary, because the new perennial energy crops are characterized by irregular returns over their life-span.

Thus, the decision problem is an intertemporal one where the farmer's time attitude needs to be accounted for. In the standard NPV approach (M_0 model), the farmer's objective function can be written as:

$$\max_{x_0, x_l} \sum_t \left(\frac{l}{1+\rho} \right)^{t-1} (x_0 r_0 + x_l r_{l,t}) \qquad s.t. \quad x_0 + x_l \leq L \tag{1.1}$$

where ρ is the discount rate or rate of time preference (RTP)(ρ>0); x_0 the acreage allocated to the traditional cropping system; x_l the acreage allocated to the innovative cropping system; r_0 the annual return (net margin) of the traditional cropping system; and $r_{l,t}$ the annual return (net margin) of the innovative cropping system.

1.2.1 Liquidity constraints and intertemporal choices

While most of the cost-benefit studies are based on the previous NPV approach, they seldom refer to the underlying assumptions. In particular, this financial calculation can explain intertemporal choices only if capital markets operate perfectly (Frederick et al., 2002; Hardaker et al., 1997). Otherwise, decision-makers are likely to face liquidity constraints and may prefer regular incomes over irregular ones. Such preferences can be specified within the DU model which defines the decision-maker's objective function as the discounted sum of the instantaneous utilities of dated consumption flows. In this framework, the representative farmer's programme is (M_1):

$$\max_{x_0,x_l} \sum_t \left(\frac{1}{1+\delta}\right)^{t-1} u(x_0 r_0 + x_l r_{l,t}) \qquad s.t. \quad x_0 + x_l \leq L \tag{1.2}$$

where δ is the *utility* discount rate or *pure* rate of time preference $\delta > 0$; and u is the farmer's *instantaneous* utility function, assumed to be stationary across time but non linear. In this context, the utility discount rate δ applies to *utils* rather than monetary units. It is linked with the RTP ρ according to:

$$1 + \rho = \frac{u'(\pi_t)}{u'(\pi_{t+l})(1+\delta)}$$

where $\pi_t = x_0 r_0 + x_l r_{l,t}$ is the dated farm profit and $\frac{u'(\pi_t)}{u'(\pi_{t+l})}$ is the ratio of the present and future marginal utilities. Thus, the pure RTP captures the preference for the present irrespective of the utility function concavity.

For the instantaneous utility function, we choose an exponential form, which both allows curvature to be represented by a single parameter and is defined over negative values:

$$u(\pi_t) = 1 - e^{-\alpha \pi_t}$$

where α is a (strictly) positive parameter representing the concavity of the utility function and the farmer's preference for flat income profiles. This preference is often measured by $\frac{1}{w.\alpha}$, called the elasticity of intertemporal substitution (EIS), and where w is the decision-maker's wealth. The higher α, the lower the EIS, and the more averse the farmer to intertemporal income fluctuations.

1.2.2 Uncertainty and intertemporal choices

In the previous paragraph, we voluntarily limited our analysis to a certain setting. However, agriculture is by nature a risky activity, and farmers' risk attitudes are known to deeply influence their choices, especially when dealing with a new technology. We chose to focus on market risk for two main reasons. Firstly, the tendency towards the liberalization of agricultural markets and its effect on price volatility, particularly visible in 2007 and 2008, has raised new concerns about price risk issues. Secondly, perennial energy crops are sold on an emerging market in France, and thus, farmers may face a lack of outlets. We assume that traditional and innovative technology price risks are not correlated because outputs are sold on two different markets, respectively the food and energy markets. The additional production risk which is usually considered in the case of a new technology is not accounted for in this paper. Indeed, it does exist for perennial energy crops at the critical establishment phase but it becomes weak during the following periods because miscanthus and switchgrass are particularly resistant to drastic climatic conditions and disease (Bocquého, 2008).

We follow the EU framework to model farmers' decision under uncertainty. In this part, we assume a perfect capital market that allows farmers to suffer no liquidity constraints. The representative farmer's aversion to risk is captured by a concave utility function, just like the aversion to intertemporal fluctuations. We use the same exponential utility function than in the previous part, the α positive parameter being in this case the Arrow-Pratt coefficient of absolute risk aversion (ARA). The farmer's objective function can be written as the expected utility of the NPV (M_2):

$$\max_{x_0,x_l} Eu\left[\sum_t \left(\frac{1}{1+\rho}\right)^{t-1} (x_0 r_0(\tilde{p_0}) + x_l r_{l,t}(\tilde{p_l}))\right] \qquad s.t. \quad x_0 + x_l \leq L \tag{1.3}$$

with $u(\pi_t) = 1 - e^{-\alpha\pi_t}$

where u is the farmer's *intertemporal* utility function; E is the expectation operator; π is the total profit over the time horizon and $\tilde{p_0}$ and $\tilde{p_l}$ are the random output prices of respectively the traditional and the innovative cropping systems.

1.2.3 Liquidity constraints, uncertainty, and intertemporal choices

In this part, we relax the perfect capital market assumption and propose a fourth model combining DU and EU theories. We account for liquidity constraints and farmers' risk attitudes at the same time - the farmer's objective function becomes (M_3):

$$\max_{x_0,x_l} E\left[\sum_t \left(\frac{1}{1+\delta}\right)^{t-1} u(x_0 r_0(\tilde{p_0}) + x_l r_{l,t}(\tilde{p_l}))\right] \quad s.t. \quad x_0 + x_l \leq L \tag{1.4}$$

with $u(\pi_t) = 1 - e^{-\alpha \pi_t}$.

In this last model, the curvature of the instantaneous utility function represents the farmer's preference for both flat and certain incomes, namely the α parameter refers to the EIS and the ARA coefficient at the same time. It is a measure of the farmer's aversion to income variability over time and over states of nature. Thus, we can qualify α as a coefficient of absolute *variability* aversion.

1.3 Empirical analysis

1.3.1 Data and model specification

For the empirical application we have chosen a cereal farm in the *Eure-et-Loir* department to serve as an example because it is the French department where perennial energy crops are the most widely farmed. The number of cropping systems that can be chosen by the farmer is limited to a set of two: the conventional rape/wheat/barley rotation and a perennial energy system, either switchgrass or miscanthus. Thus, the coupled subsidies the farmer can claim for are the arable crop subsidy in the first case and the energy crop subsidy in the second case. The traditional rotation is modelled by a constraint, that is traditional crop areas are set to be equal.

The parameters of the four models are identical and given in Table 1.1 and Table 1.2, cost details in Appendix A. We define two scenarios according to the perennial energy crop considered. The minimum life-span of the energy crop defines the time horizon T. The total arable land of the farm L is 100 ha, which is the average size of cereal farms in the *Eure-et-Loir* department. [1]

1. Source: Farm structure survey 2005, available at: http://agreste.agriculture.gouv.fr/enquetes/structure-des-exploitations/.

Table 1.1: Parameter data for perennial energy crops

Parameter	Symbol	Unit	Value according to time period				
Time-period	t	year	1	2	3	4 to T-1	T
Switchgrass							
Life-span	T	years	10				
Yield	y_t	t/ha	0	8	13	13	13
Average output price	p	€/t	70	70	70	70	70
Variable costs	c_t	€/ha	793	299	249	292	456
		€/t		34	17	20	33
Coupled subsidy	s	€/ha	32	32	32	32	32
Miscanthus							
Life-span	T	years	15				
Yield	y_t	t/ha	0	0	12	17	17
Average output price	p	€/t	70	70	70	70	70
Variable costs	c_t	€/ha	3,819	70	244	321	470
		€/t			18	17	26
Coupled subsidy	s	€/ha	32	32	32	32	32

Table 1.2: Parameter data for farm, farmer, and traditional crops

Parameter	Symbol	Unit	Value
Total arable land	L	ha	100
Rape			
Yield	y_t	t/ha	3.5
Average output price	p	€/t	213.4
Variable costs	c_t	€/ha	386
		€/t	110
Coupled subsidy	s	€/ha	96
Soft wheat			
Yield	y_t	t/ha	7.5
Average output price	p	€/t	98.5
Variable costs	c_t	€/ha	480
		€/t	64
Coupled subsidy	s	€/ha	96
Winter barley			
Yield	y_t	t/ha	7.8
Average output price	p	€/t	106.4
Variable costs	c_t	€/ha	452
		€/t	58
Coupled subsidy	s	€/ha	96
Farmer's preferences			
RTP	r	%	5
Pure RTP	d	%	5

Herbaceous energy crop data

We mainly draw our switchgrass and miscanthus data from field interviews we had with farmers and other stakeholders in the *Eure-et-Loir* area in summer 2008 (Bocquého, 2008). They provided us with information about yields, variable costs, and crop management. Yields correspond to late winter harvesting on land of rather good quality which is dominant in *Eure-et-Loir*. Regarding costs, we assume that farm overhead and general equipment fixed costs (depreciation, insurance and financing costs) are paid no matter the crop, and thus, they are not accounted for. We thus only consider variable production costs, which encompass three categories: operating costs, machinery costs and labour costs (see Appendix A, Table A.1). In the first category we include seeds (or rhizomes), fertilizers, herbicides, contractor services and plastic sheeting for storage.

We assume that the planting of miscanthus rhizomes is done by a contractor because it requires a specific planter, whereas switchgrass is supposed to be sowed by the farmer with a classic wheat sower. As for harvesting, we consider that it is done by a contractor for both crops and we use the market price of such a service. The technique used is the cheapest one, that is a silage harvester that delivers chopped material. Because the farmers at the time they were interviewed were not able to communicate the exact costs of storage and uprooting, we use European values respectively from (Smeets et al., 2009; Styles et al., 2008). Storage is in the open air with plastic sheeting. The second category is for machinery costs when the farm equipment is used. Data on machinery use derive from local extension services.[2] As stated before, we only report variable costs (fuel, lubrification, repairs, and tires) because we assume that the farmer keeps the same machinery when deciding to grow perennial energy crops. It is a reasonable hypothesis as long as traditional crops remain the principal activity. Data on machinery also include work capacities, which is useful to infer farmer's workloads and calculate labour costs, which is the third cost category. The price of labour is set equal to the legal minimum wage in France (SMIC) in the year 2007, that is 8.4€/h. Details on crop management and corresponding cost calculations can be found in (van Boxsom and Bocquého, 2009). Regarding the energy crop subsidy, it is the coupled part effectively received by farmers in the 2006/2007 crop year.[3] Note that the energy-crop return profiles are irregular over time,

2. Source: Barème d'entraide 2008, Chamber of Agriculture of *Loir-et-Cher*, available at: .
3. Source: Agence Unique de Paiement.

particularly for miscanthus, mainly due to the establishment period (Table 1.1).

Traditional crop data

As far as traditional crops are concerned, yields are the average value over the last ten available years (1998-2007) for the *Eure-et-Loir* region. [4] Corresponding management practices and input costs are provided by 2006/2007 national references (Teyssier, 2007). The arable crop coupled subsidy (for dry cropping) is calculated from government statistics for the 2006/2007 crop year in the *Eure-et-Loir* department. [5] Annual yields, costs, and subsidies are supposed to be constant over time.

Output prices

Output prices are supposed to be independent from the time period. When uncertainty is accounted for (M_2 and M_3 models), we assume that they follow a normal probability distribution (5,000 runs) whose parameters are derived from historic price mean and standard deviation. We define two scenarios according to the price series considered. On the one hand, we use data over the 10 years prior to the exceptional 2007/2008 crop year, when prices have been exceptionally high. The corresponding mean and standard deviation for wheat price are 98.5 €/t and 15 €/t, and the coefficient of variation, which is used as a measure of the price volatility, is 15%. [6] On the other hand, we calculate the same parameters adding the 2007/2008 data to the 1997/1998–2006/2007 series. We calculate a mean wheat price of 109.5 €/t with a coefficient of variation of 35%. This scenario is qualified as a high volatility scenario. As we assume that all traditional crop prices are perfectly correlated, we infer the price distribution parameters for rape and barley from the wheat ones, using linear regression results. We find that the price mean and volatility of rape and barley calculated with this method are closed to the historic values, except the rape price volatility which is overestimated.

As for energy crops, due to the lack of data series, we assume that prices potentially has the same volatility as wheat prices, that is 15% or 35%. We suppose that traditional and energy crop prices are independent. For the mean price, we use a 70 €/t value, according to our field

4. Source: Annual agriculture statistics 2007, available at: http://www.agreste.agriculture.gouv.fr/publications/chiffres-et-donnees/article/statistique-agricole-annuelle-5924.

5. Source: Agence Unique de Paiement.

6. Source: Annual market analysis, grain and forage crops, available at: http://agreste.agriculture.gouv.fr/conjoncture/grandes-cultures-et-fourrages/.

interviews. In the M_0 and M_4 deterministic models, traditional and energy crop prices are set equal to the mean prices.

Preference parameters

The discount rate ρ used in the M_0 and M_1 models is set equal to 5%, like in many perennial energy crop economic assessments (Goor et al., 2000; Styles et al., 2008; Toivonen and Tahvanainen, 1998; van den Broek et al., 1997). It is also the value of the market interest rate for French farmers (Teyssier, 2007). In order to compare M_0 and M_1 with M_2 and M_3, and because the many studies which attempted to elicit individuals' time preferences failed to identify reliable values (Frederick et al., 2002), we use the same value for the utility discount rate δ. However, we lead a sensitivity analysis of our four models to the farmer's time preference in Section 1.3.3.

The ARA coefficient (α) of 1.4 x 10^{-5} €$^{-1}$ (M_2 and M_3) characterises in our modelling a rather risk averse farmer. It is calculated thanks to the formula linking the absolute and relative (RRA) risk coefficients $RRA = w \cdot ARA$, where w is the total wealth of the decision-maker, proxied by the farm fixed assets. We use a RRA coefficient of 2.0 (Hardaker et al., 1997) and a fixed asset value of 140 k€.[7] In M_3, aversion to intertemporal fluctuations is merged with aversion to risk. Again, to be able to compare the models, we choose the same value for α in M_1 as in M_3. As decision-makers' risk and intertemporal substitution attitudes depend strongly on their socio-demographic characteristics and economic environment, we also study the sensitivity of our models to the coefficient of variability aversion in Section 1.3.2.

1.3.2 Simulation results

In a first part we lead adoption simulations with the four models and under the two 15% and 35% price volatility hypotheses for M_2 and M_3. In France, most of perennial energy crops are traded through supply contracts with process plants, mainly fodder and beet pulp dehydration plants (Bocquého, 2008). These contracts can include different features, for instance regarding price and financing arrangements. Thus, energy crop price volatility and return patterns should

7. Source: Farm Accountancy Data Network 2007, cereal farms from 40 to 100 ha of the *Centre* region, available at: http://www.agreste.agriculture.gouv.fr/publications/chiffres-et-donnees/article/rica-france-tableaux-standard-2010.

Table 1.3: Switchgrass and miscanthus optimal acreages according to four different models of adoption

Model	Price volatility scenarios	Switchgrass		Miscanthus	
		optimal acreage (ha)	total return[a] (€/ha/yr)	optimal acreage (ha)	total return[a] (€/ha/yr)
M_0	N/A	0	432	0	432
M_1	N/A	0	432	0	432
M_2	Low (15%)	32.1	430	7.4	427
	High (35%)	34.5	430	20.7	417
M_3	Low (15%)	1.2	432	0	432
	High (35%)	9.6	431	0	432

[a] The total return is the annualised (expected) NPV of returns from both traditional and perennial cropping systems.

depend strongly on these contracts, as well as adoption. In a second part, we define three alternative scenarios to assess the effect of contractual arrangements on the extent of energy crop adoption. Departing from the baseline scenarios, we assume that energy crops are sold through specific supply contracts. According to the agreements generally encountered in the field between farmers and process plants (or intermediaries), we define two basic contracts: the one guarantees a fixed price over the whole crop life-span, the other offers the possibility to the representative farmer to smooth establishment costs on several years (Bocquého, 2008). We analyse the effect of these two common features of supply contracts on energy crop adoption independently and then jointly, using the relevant models.

Baseline scenarios

The optimal extent of energy crop adoption according to our four models is displayed in Table 1.3. We also provide the ensuing total expected return from all the crops. With the cost and price data we use, the annualised expected return of switchgrass and miscanthus are respectively 426 €/ha/yr and 359 €/ha/yr, at a 5% discount rate. The one of the traditional cropping system (rape/wheat/barley rotation) is 432 €/ha/yr. Thus, according to the base NPV model (M_0), the farmer had better not grow any energy crop. Nevertheless, if we imagine that all direct crop subsidies are suppressed, following the CAP evolution tendency, switchgrass becomes more profitable than the traditional rotation (394 €/ha/yr superior to 336 €/ha/yr).

Miscanthus is still not economically efficient (327€/ha/yr) when compared to traditional crops. The corresponding break even prices drop to 65€/t and 71€/t. Of course, when liquidity constraints are accounted for (M_1), we obtain the same results as with the M_0 model, namely none of the energy crops is competitive. The break even energy crop prices remain the same despite the farmer's aversion to irregular return patterns. When we add only uncertainty to the M_0 model (M_2), energy crop optimal acreages get much higher than in the M_1 model because of the farmer's risk aversion positive effect on adoption. Indeed, energy crops lower the total return volatility, even if they decrease its expected value at the same time. The higher the energy crop NPV and the price volatility, the larger the extent of the energy crop adoption. In the low volatility scenario, it is optimal to grow 32.1 ha of switchgrass or 7.4 ha of miscanthus, the latter being penalized by its lower profitability (in terms of NPV). In the high volatility scenario, optimal areas raise to 34.5 and 20.7 ha respectively. The corresponding total expected returns are 430€/ha/yr and 427€/ha/yr, which are only 0.5% and 3.6% lower than the expected return of the traditional cropping system. This diversification strategy is one well-known technique for farm risk management. Our results suggest that it could lead to energy crop adoption on a rather large extent, even if the profitability is smaller. Nevertheless, the results strongly depend on the price volatility perceived by the farmer. If liquidity constraints and uncertainty are taken into consideration at the same time (M_3), energy crop benefits are strongly mitigated by their negative effect on income stability over time. Indeed, only switchgrass is able to compete. It is optimal to grow switchgrass on 1.2 ha when price volatility is around 15%, and on 34.5 ha when it is 35%. Thus, the advantage of diversifying with energy crops is strongly outweighed by the additional liquidity needs, specifically in the miscanthus case.

Supply contract scenarios

In these scenarios we study the impact on optimal energy acreages of two common features of biomass supply contracts. The first set of runs simulates the effect of a long term price guarantee of 70€/t on M_2 and M_3 optimal energy acreages. It is equivalent to suppressing price risk on energy crops. The results show that the fixed price effect is strong with M_2 (energy acreages multiplied by 3 or 4), whereas it is weak with M_3. Indeed, switchgrass acreages are only slightly higher than in the baseline case (3.2 ha against 1.2 ha if volatility is low, 11.5 ha against

Table 1.4: Switchgrass and miscanthus optimal acreages in different supply contract scenarios

Model	Price volatility scenarios	Contract scenarios	Optimal acreage (ha)	
			Switchgrass	Miscanthus
M_1	N/A	**baseline**	0	0
		1.5% loan	40.4	2.8
		4 % loan	9.10	0
		5 % loan	0	0
M_2	Low (15%)	**baseline**	32.1	7.4
		fixed price	90.8	33.7
	High (35%)	**baseline**	34.5	20.7
		fixed price	97.7	86.9
M_3	Low (15%)	**baseline**	1.2	0
		1.5% loan	36.3	5.7
		4% loan	26.9	0
		5% loan	14.7	0
		fixed price	3.2	0
		1.5% loan+fixed price	51.0	6.1
		4% loan+fixed price	28.1	0
		5% loan+fixed price	18.8	0
	High (35%)	**baseline**	9.6	0
		1.5% loan	33.6	12.0
		4% loan	28.6	2.6
		5% loan	11.5	0
		fixed price	78.1	0
		1.5% loan+fixed price	79.8	19.6
		4% loan+fixed price	57.3	3.6
		5% loan+fixed price	0	0

9.6 ha if volatility is high). Miscanthus ones are still nil. Thus, a long term price guarantee is not sufficient to make miscanthus competitive with traditional crops. The second set of runs simulates with M_1 and M_3 the effect of financing the establishment costs of switchgrass and miscanthus. Farmers could be offered this opportunity by contractors or directly by banks with a long term contract as a guarantee. We model it as a loan incurred the first year to cover establishment costs and needs for some extra liquidity as there is no immediate harvest. As an example, we assume that the farmer borrows 1,000 €/ha for switchgrass and 5,000 €/ha for miscanthus. We also assume that the capital refund is over 8 years, from the first harvest date, which implies that the loan is paid-off before the end of the energy crop plantation. We run simulations for several interest rates ranging from 1.5 to 5% (Figure 1.1).

The 1.5% rate corresponds to a loan subsidized by authorities; it is the rate currently offered

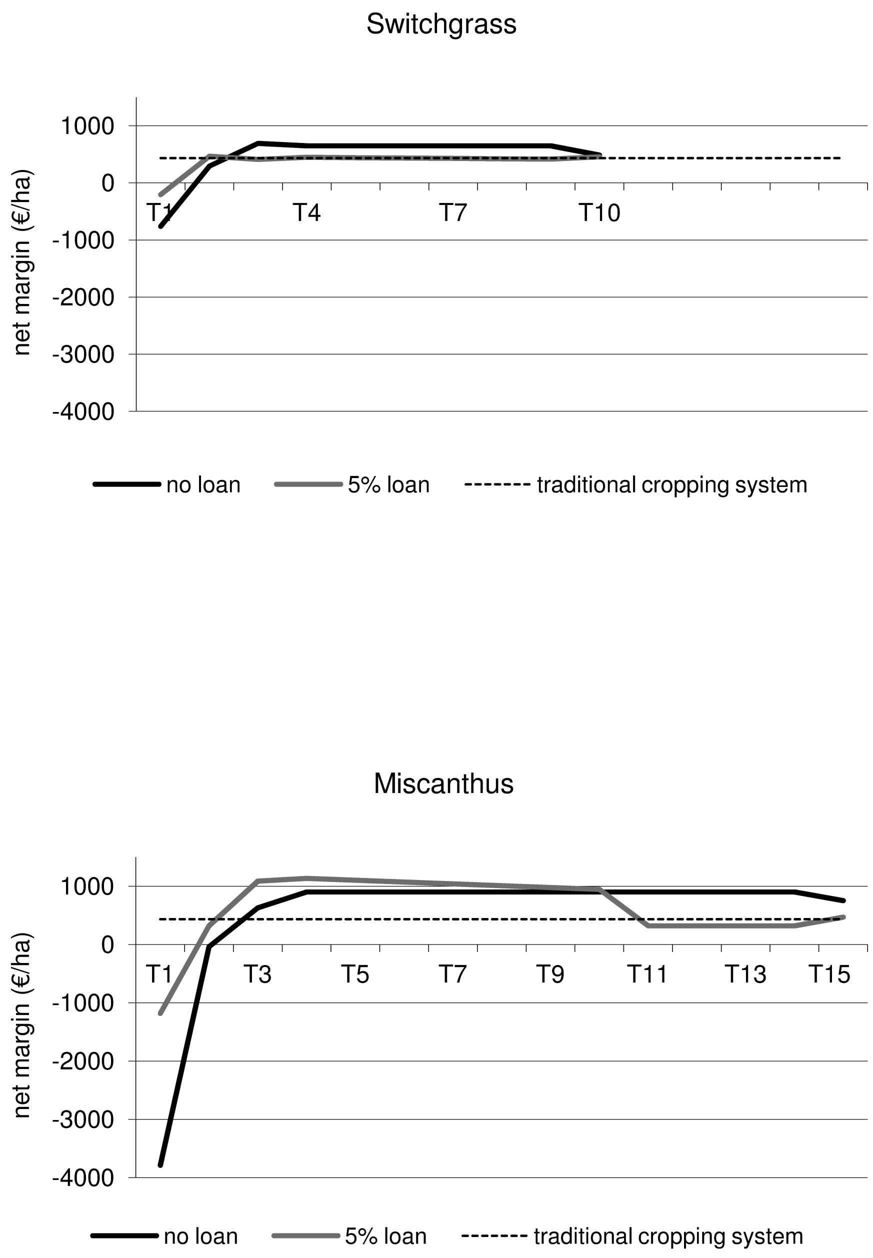


Figure 1.1: Perennial energy crop return patterns.

by the French government to support farmers' investments. Rates of 4% and 5% are 2007 market interest rates (Teyssier, 2007). The results are displayed in Table 1.4. In both deterministic (M_1) and stochastic (M_3) settings, financing of the establishments costs have a positive effect. Focusing on M_3 low volatility results, we find that switchgrass adoption would be strongly enhanced at a 5% interest rate (14.7 ha instead of 1.2 ha). For miscanthus, the loan should be subsidised at 1.5% as a minimum; around 6 ha would be allocated to this crop with this rate. Otherwise, loan payments reduce miscanthus profitability relatively to traditional crops too much. Nevertheless, in the high price volatility scenario, miscanthus can appear in the crop mix with a 4% interest rate.

Finally, we simulate with M_3 the cumulated effects of a loan on the first year and a fixed output price. Switchgrass is highly adopted, from 18.8 ha to 78.1 ha depending on the interest rate and the price volatility. Miscanthus acreages increase from 5.7 ha to 6.1 ha when the interest rate is 1.5% and the perceived volatility is low. In the 35% volatility hypothesis, they extend from 12.0 ha to 19.6 ha (1.5%), and from 2.6 ha to 3.6 ha (4%). Miscanthus results are of the same order than what is actually observed among French *Eure-et-Loir* farmers: in this department, the average acreage cultivated by miscanthus producers is around 4 ha (Bocquého, 2008). At a 5% interest rate, it is never optimal to grow miscanthus. Thus, our results suggest that reducing farmers' liquidity constraints would be more effective to enhance perennial energy crop adoption by farmers than guaranteeing a fixed price. It is particularly true in the miscanthus case because this crop has a much more irregular return profile than switchgrass. However, the response depends on the hypotheses made about energy crop price volatility. In the absence of such information, we have chosen to set it into line with that of traditional crops, that is 15% or 35%. If we had accounted for the price risk due to either a lack of outlets because of the emerging nature of the biomass market in France, or a drop in biomass prices because of a supply excess, we may have found that guaranteeing long term prices through contracts would have impacted farmers' decisions much more. Moreover, several other possibilities exist for energy crop price calculation in supply contracts. The most general agreement is an indexation to energy price (crude oil, diesel, coal, wood), often according to the fuel being replaced by the contractor. The index can also mix several fuel prices at the same time and include other items like labour price. Part of the price can be indexed, and the rest be fixed (Bocquého, 2008). All these combinations depend on the negotiation between the farmer and the biomass processor. In such price arrangements, volatility concerns probably play an important role, but farmers' expectations on future price trends may also be significant. If we assume that farmers' expectations follow the official outlooks (Appendix B), we can infer that farmers may rely on energy price increasing quicker in the mid-term than cereal price. Indeed, projections suggest a 56% oil price increase between 2007 and 2018, but only a 20% increase for wheat prices. Though, the main issue when discussing results and contract effects is probably the reliability of farmers' time and intertemporal preference parameters. In the next section, an analysis of model sensitivity to both their preference for the present and their willingness to smooth income over time is exposed, along with sensitivity to energy crop life-span.

1.3.3 Parameter sensitivity analysis

To begin with, we assess the sensitivity of the four base models to the preference parameters, that is ρ and δ on the one hand (preference for the present), and α on the other hand (aversion to variability), which also represents the utility function curvature. Indeed, they all refer to heterogeneous farmers' individual attitudes, which vary with numerous socio-demographic and economic factors. In the case of M_2 and M_3, we only consider the low price volatility scenario. The results are displayed in Table 1.5 and Table 1.6.

Respect to the time preference sensitivity (Table 1.5), we can observe that in terms of NPV (M_0), switchgrass gets more profitable than the traditional rotation when the rate is inferior or equal to 3%, and miscanthus when it is lower than 1%. When adding liquidity constraints (M_1), they also appear in the optimal crop mix but to a smaller extent. As for optimal energy acreages under uncertainty (M_2), they are sensitive to the discounting as well. For rates ranging from 0 to 10%, switchgrass acreages range from 13.3 to 42.6 ha, and for rates ranging from 5 to 10%, miscanthus acreages range from 7.4 to 32.9 ha. Indeed, the higher the discount rate, the more important the establishment costs relatively to future incomes. In the mixed M_3 model, switchgrass acreages are positive only when the discounting is 5% or lower (1.2 to 12.6 ha), while miscanthus needs the discounting to decrease to 1% at least (2.2 ha and 3.4 ha when there is no discounting).

Regarding aversion to variability (Table 1.6), we cannot observe any influence on M_1 results

Table 1.5: Result sensitivity to the farmer's time preference

Model	Preference for the present	Optimal acreage (ha)	
		Switchgrass	Miscanthus
M_0	None (ρ=0%)	100	100
	Very slight (ρ=1%)	100	100
	Slight (ρ=3%)	100	0
	Intermediate (ρ=5%)	0	0
	Rather strong (ρ=8%)	0	0
	Strong (ρ=10%)	0	0
M_1	None (δ=0%)	10.6	9.1
	Very slight (δ=1%)	8.0	1.8
	Slight (δ=3%)	2.9	0
	Intermediate (δ=5%)	0	0
	Rather strong (δ=8%)	0	0
	Strong (δ=10%)	0	0
M_2	None (ρ=0%)	42.6	32.9
	Very slight (ρ=1%)	41.1	29.7
	Slight (ρ=3%)	37.2	20.7
	Intermediate (ρ=5%)	32.1	7.4
	Rather strong (ρ=8%)	22.0	0
	Strong (ρ=10%)	13.3	0
M_3	None (δ=0%)	12.6	3.4
	Very slight (δ=1%)	10.3	2.2
	Slight (δ=3%)	5.6	0
	Intermediate (δ=5%)	1.2	0
	Rather strong (δ=8%)	0	0
	Strong (δ=10%)	0	0

Simulations with a price volatility of 15%.

Table 1.6: Result sensitivity to the farmer's variability preferences

Model	Aversion to return variability	Optimal acreage (ha)	
		Switchgrass	Miscanthus
M_0	N/A		
M_1	Hardly averse to irregular return patterns ($\alpha = 0.5/w$)	0	0
	Somewhat averse to irregular return patterns ($\alpha = 1.0/w$)	0	0
	Rather averse to irregular return patterns ($\alpha = \mathbf{2.0/w}$)	0	0
	Very risk averse to irregular return patterns ($\alpha = 3.0/w$)	0	0
	Extremely averse to irregular return patterns $\alpha = 4.0/w$)	0	0
M_2	Hardly risk averse ($\alpha = 0.5/w$)	24.6	0
	Somewhat risk averse ($\alpha = 1.0/w$)	29.7	0
	Rather risk averse ($\alpha = \mathbf{2.0/w}$)	32.1	7.4
	Very risk averse ($\alpha = 3.0/w$)	33.0	13.0
	Extremely averse ($\alpha = 4.0/w$)	33.5	15.6
M_3	Hardly averse to risk and irregular return patterns ($a = 0.5/w$)	0	0
	Somewhat averse to risk and irregular return patterns ($a = 1.0/w$)	0	0
	Rather averse to risk and irregular return patterns (a = 2.0/w)	1.2	0
	Very averse to risk and irregular return patterns ($a = 3.0/w$)	1.8	0
	Extremely averse to risk and irregular return patterns ($a = 4.0/w$)	2.1	0

Simulations with a price volatility of 15%.

because of the energy crop very low profitability in terms of NPV. On the contrary, the α value modifies M_2 results. If we consider different representative farmers, ranging from hardly (RRA=0.5) to extremely averse to income variability (RRA=4.0), optimal switchgrass acreages vary from 24.6 to 33.5 ha, and miscanthus ones from 0 (RRA=0.5 or 1.0) to 15.6 ha. Thus, M_2 sensitivity to the ARA coefficient is of the same order than its sensitivity to the discount factor. In the mixed M_3 model, only farmers rather, very or extremely averse to variability would grow switchgrass (1.2 to 1.8 ha), while miscanthus would never be planted. In this last model, aversion to risk and aversion to intertemporal fluctuations are merged in the same α parameter although they have an opposite effect on energy crop adoption.

We also analyse the impact of the energy crop life-span on the simulation results (Table 1.7).

Table 1.7: Result sensitivity to the perennial energy crop life-span

Model	Life-span extension	Optimal acreage (ha)	
		Switchgrass	Miscanthus
M_0	**None (T=10 or 15 yr)**	0	0
	3 years (T=13 or 18 yr)	100	0
	5 years (T=15 or 20 yr)	100	100
	10 years (T=20 or 25 yr)	100	100
M_1	**None (T=10 or 15 yr)**	0	0
	3 years (T=13 or 18 yr)	12.4	0
	5 years (T=15 or 20 yr)	19.3	0.8
	10 years (T=20 or 25 yr)	31.4	3.3
M_2	**None (T=10 or 15 yr)**	32.1	7.4
	3 years (T=13 or 18 yr)	45.0	21.4
	5 years (T=15 or 20 yr)	48.0	26.8
	10 years (T=20 or 25 yr)	50.9	33.9
M_4	**None (T=10 or 15 yr)**	1.2	0
	3 years (T=13 or 18 yr)	14.1	0
	5 years (T=15 or 20 yr)	20.4	1.2
	10 years (T=20 or 25 yr)	31.4	3.7

Simulations with a price volatility of 15%.

We do know switchgrass and miscanthus can still produce in their 10th and 15th year, but some trial plots well exceed this limit. Thus, we consider hypothetical life-span extensions of 3, 5, and 10 years, assuming that annual yields do not decrease over time. The life-span effect on M_0 and M_1 switchgrass results is important, with acreages ranging from 12.4 to 31.4 ha in the second case. Miscanthus only appears if the time horizon is extended from 15 to 20 years, but acreages remain small (less than 4 ha). The stochastic simulation results (M_2) are modified by life-span extensions as well, switchgrass acreages rising from 32.1 ha (10-year life-span) to 50.9 ha (20-year life-span), and miscanthus ones from 7.4 ha (15-year life-span) to 33.9 ha (25-year life-span). As to M_3 optimal acreages, when the life-span is extended by 10 years without any yield loss, they reach 31.4 ha in the case of switchgrass and 3.7 ha only in the case of miscanthus.

1.4 Conclusion

We show with a standard NPV analysis (M_0) that, in the French *Eure-et-Loir* department setting, switchgrass and miscanthus are less profitable for a farmer than a traditional rotation of arable crops. This is in line with the results obtained in recent studies when comparing wheat with switchgrass in Italy (Monti et al., 2007), and wheat with miscanthus in Ireland (Deverell et al., 2009; Styles et al., 2008), who also studied miscanthus in Ireland, find a 383€/ha/yr gross margin (chopped material), which is similar to the one we have calculated for France (399€/ha/yr). Although they conclude that miscanthus is highly competitive with winter wheat or spring barley, their conventional crop calculations rely on 2004 output prices, which were particularly low, and on a total decoupling of CAP payments, which was not applied simultaneously to energy crops.

We also show that liquidity constraints and price risk are both very important factors influencing the intensity of switchgrass and miscanthus adoption forecasted by models. While a NPV model (M_0) concludes that these crops should not be farmed at all, an expected utility model (M_2) shows that they can be competitive with traditional crops. Indeed, their selling on an energy market disconnected from the food one gives them a strong advantage. Diversifying with crops having independent prices lowers the global income risk, especially when price volatility is expected to be high. However, their irregular return pattern tends to restrain their adoption, as suggested by a stochastic discounted utility model (M_3). In the miscanthus case, the advantage of diversification is even completely outweighed. In fact, miscanthus is much less competitive than switchgrass because of its low NPV and its important year-to-year return variability, meaning that large liquidities are required for its farming.

Nevertheless, in the first set of simulations, we do not take into account the existence of supply contracts, although it is a very common practice in France. Indeed, most of perennial energy crops are traded with process plants through long term contracts. Therefore, in a second set of simulations, we represent explicitly different types of contracts and assess their effect on perennial energy crop adoption. In particular, we study two frequent contractual arrangements, that is the guarantee of a fixed price over the crop life-span on the one hand, and the possibility for farmers to finance establishment costs trough a loan on the other hand. We show that such arrangements, especially the second one, can be powerful means of stimulating farmers' willingness to grow energy crops. The fixed price contract increases switchgrass and miscanthus usefulness as diversification crops, whereas the loan like contract decreases farmers' liquidity needs. Overall, our results point out the fact that offering to farmers contracts which are attractive enough is most probably a condition for the development of a secured supply for process plants in the long run. Further studies are needed to validate empirically the extent to which contracts are needed, and define precisely the features that would match farmers' risk and time preferences best. Choice experiments including more diversified contractual arrangements and scenarios could moreover highlight other determinants of adoption, like farmers' environmental preferences or policy anticipations.

Chapitre 2

Les caractéristiques de la production d'herbacées pérennes énergétiques en France : l'exemple du miscanthus en Bourgogne.

Malgré l'immaturité du process de transformation en biocarburants, les cultures lignocellulosiques pérennes sont déjà exploitées en Europe pour produire de l'énergie. Il s'agit de chaleur et d'électricité obtenues à partir de la combustion de la biomasse. Dans certains pays d'Europe du Nord (Suède, Royaume-Uni, Finlande) cette filière a déjà fait l'objet d'un développement industriel à grande échelle, mais en France elle est encore émergente. Les premières cultures pérennes énergétiques introduites dans les exploitations agricoles dans un objectif commercial (et non principalement expérimental) ont été plantées en Bretagne en 2005. A l'échelle nationale, les surfaces sont encore anecdotiques, mais elles connaissent un accroissement rapide. Le miscanthus, le panic érigé, et les taillis à courte (et très courte) rotation à destination énergétique représentaient environ 1 180 ha de terres agricoles en 2007, 1 560 ha en 2008 et 2 660 ha en 2009, soit 0,01% des terres arables.[1] ,[2]

1. Surfaces ayant fait l'objet d'une déclaration pour l'obtention d'une des deux aides couplées Jachère Industrielle et Aide aux Cultures Energétiques. Surfaces d'eucalyptus à vocation papetière exclues. Source : Agence Unique de Paiement et Agreste Statistique Agricole Annuelle, traitements des auteurs. Les statistiques correspondantes pour les années 2010 et suivantes ne sont pas disponibles en raison de la suppression des aides en 2010.

2. En raison de leur rotation sur 5 ou 10 ans au lieu de 1 an pour le miscanthus et le panic érigé, les taillis demandent un matériel de récolte spécifique et leur conduite est plus proche de la sylviculture. De plus, ils sont

Le miscanthus est largement majoritaire, il représente en 2009 60% des surfaces avec 1 600 ha cultivés (le panic érigé seulement 5%). La répartition du miscanthus et du panic érigé sur le territoire est très inégale, les filières se développant à partir d'initiatives locales. Les deux conditions qui semblent nécessaires sont une demande locale (par exemple chaudières à biomasse municipales, usines de déshydratation de fourrage) et des promoteurs actifs en termes de soutien technique et commercial, qu'ils soient privés (commerçants en rhizomes, en biomasse, et/ou transformateurs) ou publics (Chambres d'agriculture) (Bocquého, 2008).

La région Centre est l'une des plus dynamiques depuis les débuts du miscanthus et du panic érigé en France. En 2009, elle est la première région en termes de surfaces pour les deux cultures (370 ha de miscanthus, soit 23% du total national en miscanthus, 80 ha de panic érigé, soit 62% du total en panic).[3] Le miscanthus est promu par la société privée Novabiom (ex-Bical France) implantée en Eure-et-Loir tandis que la filière panic érigé s'organise autour d'un groupe d'agriculteurs affilié à la Chambre d'agriculture de Tours (Indre-et-Loire).

D'autres régions ont vu leurs surfaces s'envoler plus récemment. La Bourgogne est l'une d'entre elles. En 2009, elle était la quatrième région productrice de miscanthus derrière le Centre, la Champagne-Ardennes et la Bretagne (150 ha, soit 9% du total national) et la deuxième région productrice de panic érigé derrière le Centre (30 ha, 24% du total national). En 2010, les surfaces cumulées atteignaient déjà 351 ha (14% du total national en miscanthus et panic érigé, au lieu de 10% en 2009).[4] En Bourgogne, la promotion du miscanthus est assurée à la fois par les transformateurs (coopératives de déshydratation d'Aiserey et Baigneux-les-Juifs en Côte d'Or[5]) et par la Chambre d'agriculture régionale.

Dans ce chapitre, nous décrivons en détail les caractéristiques de la production d'herbacées pérennes dans une poche de diffusion française. L'objectif est de répondre aux questions suivantes :

1. Quelles sont les pratiques agronomiques des agriculteurs dans la culture de miscanthus ?

fréquemment utilisés pour leur fonction épuratoire sur des sols pollués. Les taillis sont donc davantage implantés sur des terres non agricoles : propriétaires forestiers, collectivités, entreprises privées. Ces chiffres n'en tiennent pas compte.

3. Surfaces ayant fait l'objet d'une déclaration pour l'obtention d'une des deux aides couplées Jachère Industrielle et Aide aux Cultures Energétiques. Source : Agence Unique de Paiement, traitements des auteurs.

4. Source : Agreste Bourgogne n°123, Novembre 2011, disponible à : http://www.agreste.agriculture.gouv.fr/IMG/pdf_D2111A01.pdf.

5. L'usine de Baigneux-les-Juifs déshydrate principalement de la luzerne pour l'alimentation du bétail. La sucrerie d'Aiserey a fermé début 2008, mais l'outil de déshydratation des pulpes de betterave est toujours opérationnel. La société chargée d'adapter cet outil à la déshydratation du miscanthus est la société *Bourgogne Pellets*.

Sont elles compatibles avec les objectifs de développement durable ?

2. Quelles sont les conditions économiques qui permettent la diffusion des herbacées pérennes énergétiques ?

3. Quelles sont les perceptions des agriculteurs vis à vis des effets des herbacées pérennes sur leur exploitation ?

Les résultats sur les perceptions des agriculteurs sont utilisés dans les Chapitres 1 et Chapitres 4 pour justifier les hypothèses sur les distributions de revenus des herbacées pérennes et des cultures concurrentes. Ce chapitre donne aussi des informations supplémentaires sur le contexte géographique dans lequel l'analyse des déterminants de l'adoption du Chapitre 4 a lieu.

Nous nous appuyons sur le cas du miscanthus en Bourgogne. Ce choix s'explique par deux raisons : un développement suffisant de la production et une diversité des systèmes de production, contrairement à la région Centre. Les données proviennent d'une enquête auprès de 111 agriculteurs des bassins d'approvisionnement des usines d'Aiserey et Baigneux-les-Juifs. L'échantillon d'agriculteurs est aléatoire, stratifié sur le critère production de miscanthus (agriculteurs adoptants) ou non (agriculteurs non adoptants). [6] Les entretiens ont été réalisés de février à juin 2010 dans 64 communes de Bourgogne essentiellement (Côte d'Or et Saône-et-Loire), mais aussi de Franche-Comté (Jura) (voir Figures 2.1 et 2.2).

Dans la Section 2.1 nous décrivons les pratiques agronomiques des agriculteurs (itinéraire technique, changements d'usages des sols). Ensuite, dans la Section 2.2, nous nous intéressons aux conditions économiques qui prévalent dans la région étudiée (marché, contrats, politiques publiques). Enfin, la Section 2.3, évalue les perceptions des agriculteurs quant aux effets du miscanthus sur leur activité.

2.1 Pratiques agronomiques

2.1.1 Itinéraire technique

Le miscanthus et le panic érigé sont deux graminées originaires d'Asie du sud-est et d'Amérique du Nord respectivement. Ces deux plantes se distinguent d'autres cultures énergétiques

6. La stratégie d'échantillonnage, la réprésentativité de l'échantillon et le protocole d'enquête sont détaillés et argumentés de manière approfondie au Chapitre 4.

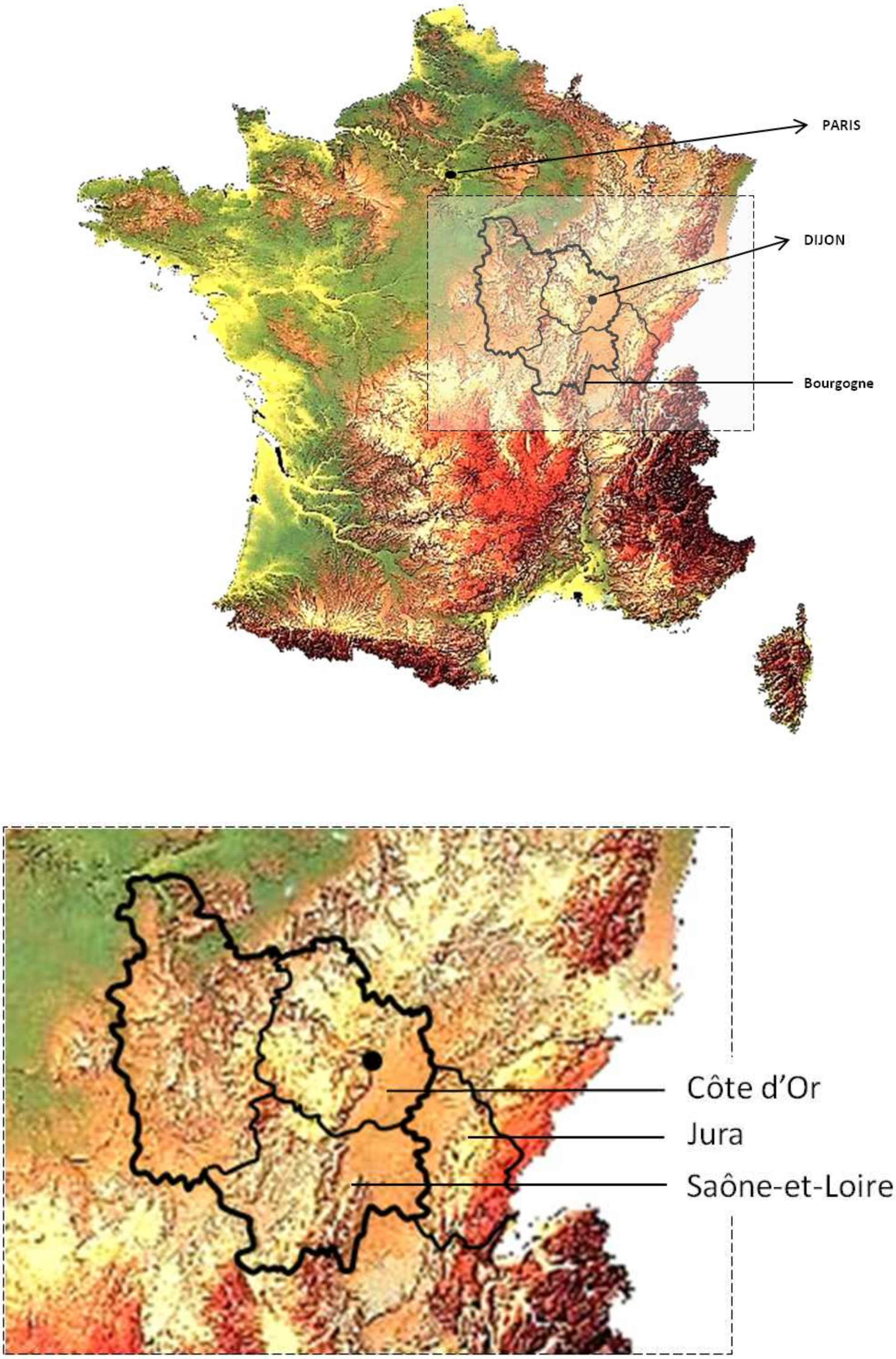


Figure 2.1 – Localisation de la zone étudiée

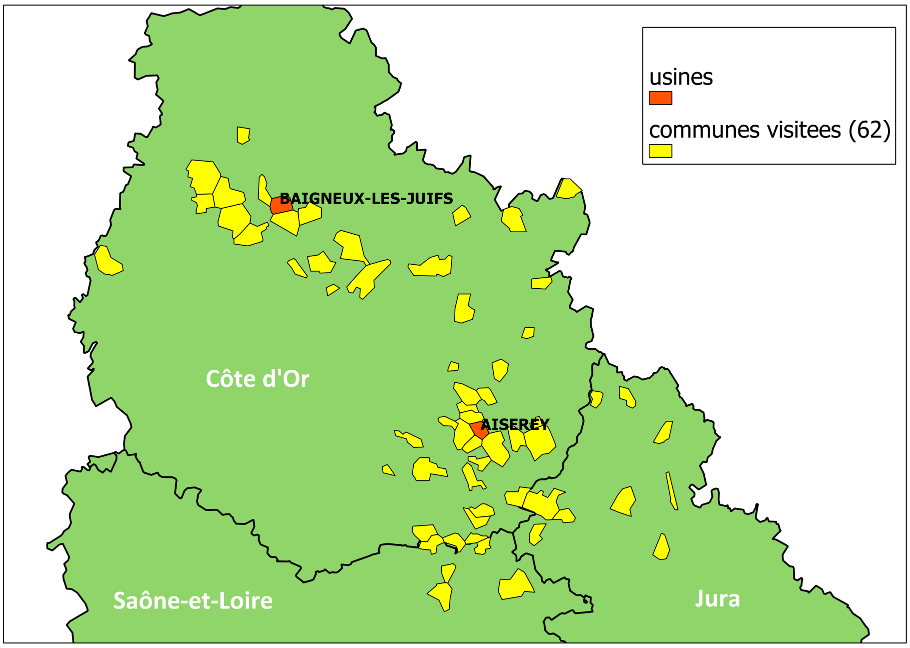


Figure 2.2 – Localisation des usines de déshydratation et des communes visitées

par un métabolisme dit en C_4 très efficace pour la production de biomasse.[7] Ces plantes peuvent s'adapter à une grande variété de sols et de climats (Lewandowski et al., 2003). Le panic érigé est légèrement avantagé sur ce point, notamment grâce à son enracinement profond (3,5 m). Le miscanthus, lui, est plus exigeant par rapport à la disponibilité en eau du sol, et craint le gel le premier hiver suivant la plantation. En revanche, la levée de dormance des graines du panic peut être difficile à obtenir et la germination très lente, ce qui le désavantage par rapport au miscanthus dans la lutte contre les adventices la première année. Le panic érigé atteint son maximum de rendement dès la troisième année de croissance alors qu'il faut 3 à 5 ans pour le miscanthus. Les cultures dépassent alors trois mètres de haut (Figure 2.3).[8]

Les conduites du miscanthus et du panic érigé sont similaires. Dans le Tableau 2.1 figure l'itinéraire technique du miscanthus tel que recommandé par les coopératives de déshydratation bourguignonnes, et tel que suivi par la quasi-totalité des producteurs de miscanthus de notre échantillon (59 agriculteurs). Cet itinéraire demande peu de travail et n'exige pas de matériel

7. Une enzyme spécifique permet d'augmenter la concentration en CO_2 dans les cellules foliaires, et d'améliorer ainsi le rendement de la réaction de photosynthèse. Même lorsque les stomates sont fermés (déficit hydrique ou obscurité), la faible pression partielle en CO_2 n'empêche pas la synthèse de matière organique. Le rendement photosynthétique dépend des conditions de température et de photopériode. La canne à sucre, le sorgho et le maïs sont des exemples d'espèces en C_4.

8. Voir Bocquého (2008) pour plus de détails sur l'histoire et les caractéristiques écologiques et biologiques des deux cultures.

(a) En été

(b) A la fin de l'hiver

Figure 2.3 – Parcelles de miscanthus

spécifique excepté pour la plantation des rhizomes qui est réalisée en prestation de services par les coopératives. La surveillance de la plantation est cruciale en première année pour que les jeunes plants ne soient pas étouffés par les adventices, et un à plusieurs passages d'herbicides sont à envisager. Les interventions sur la parcelle se limitent ensuite à la récolte annuelle, à partir de la deuxième ou troisième année. La récolte est réalisée à la fin de l'hiver et jusqu'au début du printemps, une fois les tiges sèches.[9] La chute des feuilles en automne et en hiver constitue une couverture sur le sol (mulch) qui empêche le développement des adventices et conserve l'humidité (le premier hiver la chute naturelle des feuilles est complétée par un broyage de la parcelle). De plus, les éléments minéraux des feuilles sont restitués au sol ce qui ne rend pas nécessaire l'apport de fertilisants. Par ailleurs, pendant cette même période hivernale, les minéraux de la partie aérienne du miscanthus sont transloqués vers le rhizome, ce qui limite les exportations lors de la récolte des cannes et améliore la qualité de la biomasse (Lewandowski et al., 2003). La technique de récolte privilégiée par les coopératives est le fauchage-pressage qui permet d'obtenir des balles de haute densité (Figure 2.4(a)).[10] La coopérative de Baigneux-les-Juifs prend en charge le stockage du produit tandis qu'il est à la charge des producteurs dans le cas d'Aiserey.

9. Un taux d'humidité faible est déterminant pour la qualité du combustible et la compétitivité de l'unité d'énergie produite. Il est recommandé une récolte à moins de 30% d'humidité pour des coûts de logistique et de séchage acceptables (Lewandowski et al., 2003).

10. L'ensilage est la principale alternative au fauchage-pressage. Cette technique est un peu moins coûteuse mais elle est peu adaptée aux grands volumes et aux transports sur de longues distances (produit peu dense sous forme de copeaux).

(a) Fauchage-pressage (b) Ensilage

FIGURE 2.4 – Technique de récolte

En fonction des installations dont ils disposent, 54% des producteurs livrant le miscanthus à Aiserey déclarent utiliser un abri couvert, les autres stockant simplement le produit en bout de champ sous des bâches plastiques.

2.1.2 Insertion dans les systèmes de production existants : changements d'usage des sols

Comme déjà évoqué en introduction, la durabilité des biocarburants dépend étroitement de leurs effets sur les émissions de gaz à effet de serre, la disponibilité des denrées alimentaires à des prix abordables, et la biodiversité (Directive Energies Renouvelables EU 2009/28/EC).[11]. Ces trois éléments dépendent à leur tour des changements dans l'affectation des sols (directs et indirects) induits par la culture de biomasse.

Dans cette partie, pour éclairer la question de la durabilité du miscanthus en Bourgogne, nous décrivons l'incidence de l'adoption du miscanthus par les agriculteurs de l'échantillon sur les changements (directs) d'usage des sols. Au total, les agriculteurs de notre échantillon cumulent 123 parcelles en miscanthus[12] , soit 292 ha environ (près de 5 ha en moyenne par adoptant).

Nous caractérisons le changement d'usage par le précédent cultural (rotation de cultures, prairie permanente, gel permanent, autre usage) et les sols par leur caractère marginal ou non.

11. Disponible à : http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:140:0016:0062:fr:PDF.
12. Sur ces 123 parcelles, 3 ont en fait été semées avec du panic érigé et 1 est mixte miscanthus / panic érigé. Pour simplifier, et sans que cela n'ait d'incidence notable sur les résultats présentés, nous les assimilons à des parcelles en miscanthus.

Tableau 2.1 – Itinéraire technique standard du miscanthus en Bourgogne.

<table>
<tr><th colspan="2">Année 1</th></tr>
<tr><td>Après une culture

• Préparation du sol
labour (15 j. avant la plantation au plus tard)
reprise à la herse rotative</td><td>Après une prairie permanente ou une jachère
• Préparation du sol
désherbage (septembre) : glyphosate
labour (15 j. à 3 sem. après)
reprise au vibroculteur (décembre-janvier)
reprise à la herse rotative (15 j. avant la plantation)
désherbage (si nécessaire) : glyphosate</td></tr>
<tr><td colspan="2">• Plantation (25 mars – 10 mai)
mise en terre avec une planteuse à pommes de terre modifiée : 20 500 rhizomes/ha[a]
roulage
désherbage : antigerminatif
fertilisation : aucune
• Désherbage (à vue)
antidicotylédones : 2 passsages
antigraminées : 1 passage</td></tr>
<tr><th colspan="2">Année 2</th></tr>
<tr><td colspan="2">• Maîtrise des adventices
broyage (janvier)
désherbage (10 mars – 25 mars, selon état de la parcelle) : glyphosate
antidicotylédones : 1 passage si mauvaise levée
• Fertilisation : 50 u/ha de PK
• Récolte (15 février – 10 avril), dès 8 t MS/ha
fauchage-pressage : bottes carrées
stockage : de préférence sous abri
chargement</td></tr>
<tr><th colspan="2">Années 3 à 14</th></tr>
<tr><td colspan="2">• Fertilisation : 50 u/ha de PK
• Récolte (15 février – 10 avril), >14 t MS/ha
fauchage-pressage : bottes carrées
stockage : de préférence sous abri
chargement</td></tr>
<tr><th colspan="2">Année 15</th></tr>
<tr><td colspan="2">• Remise en état de la parcelle : essais en cours</td></tr>
</table>

[a] Adjonction d'un anti-taupins pour les parcelles avec précédent prairie permanente ou jachère.

Le premier critère est usuel dans l'évaluation de la durabilité des bioénergies. Le deuxième critère varie selon la définition donnée au qualificatif *marginal*. En effet, il n'existe pas de consensus sur les caractéristiques d'une parcelle marginale. Certains auteurs privilégient une définition « utilitaire » (l'usage fait de la parcelle, ce qui revient au critère du précédent cultural), et d'autres une définition économique moins restrictive. En général, la première définition qualifie de marginales les parcelles non utilisées pour la production alimentaire. Dans cette étude, c'est le second type de définition qui est préféré : une parcelle est dite marginale si elle significativement moins rentable que le reste des parcelles de l'exploitation à cause de coûts de production élevés (y compris en travail), de rendements faibles ou d'autres contraintes. Contrairement à la définition utilitaire, cette définition est relative : si deux parcelles ont des caractéristiques similaires, l'une pourrait être qualifiée de marginale et l'autre de non marginale, en fonction des autres parcelles de l'exploitation à laquelle chacune d'entre elles appartient. De plus, la significativité de la différence de rentabilité entre parcelles a été laissée à l'appréciation des agriculteurs puisque ce sont eux qui ont désigné les parcelles marginales de leur exploitation, après que la définition économique leur ait été donnée. Ici, le caractère marginal est donc aussi une notion subjective. [13]

La ou les raisons pour lesquelles certaines parcelles sont qualifiées de marginales ont également été identifiées lors de l'enquête : qualité du sol, éloignement, taille, pente, forme, autre. Toutes ces raisons sont suceptibles de diminuer la rentabilité des parcelles,mais d'augmenter les performances du miscanthus en termes de durabilité. Par exemple, plus le potentiel de rendement est faible, plus le volume de production alternative perdu (alimentaire notamment) est faible. Plus la parcelle est éloignée, plus les émissions de gaz à effet de serre évitées sont importantes (en particulier si la production remplacée était exigeante en opérations culturales). Il en est de même pour les parcelles dont la géométrie diminue la rapidité d'exécution des opérations culturales (débit de chantier).

Dans le Tableau 2.2 figure la répartition des surfaces de miscanthus de notre échantillon en fonction du précédent cultural. Les surfaces en miscanthus se sont directement substituées à des rotations de cultures pour 66% d'entre elles, à du gel permanent pour 30%, et à des prairies permanentes à 1%. En 2009, la SAU cumulée des adoptants est utilisée à 83% par des rotations de cultures, à 11% par des prairies permanentes et à 3% par du gel permanent. [14] Il semble

13. La définition du qualificatif *marginal* est également discutée au Chapitre 4, Section 4.4.2.
14. Les chiffres sont similaires si on considère le parcellaire des non adoptants.

Tableau 2.2 – Précédent cultural des parcelles en miscanthus

Précédent cultural	Surface cumulée	
	ha	%
Rotation de cultures	193,9	66
Prairie permanente	3,5	1
Gel permanent	86,5	30
Autre usage	0,4	0
Information non communiquée	7,4	3
Total	291,7	100

donc que le miscanthus soit planté préférentiellement sur des parcelles en gel, puis sur des parcelles en culture. Les prairies permanentes paraissent très peu impactées par l'implantation de miscanthus.

Dans le Tableau 2.3 figure la répartition des surfaces de miscanthus de notre échantillon en fonction de leur caractère marginal ou non, et des raisons pour lesquelles certaines d'entre elles sont marginales. La quasi-totalité des adoptants (92%) déclare avoir des parcelles marginales. En moyenne, elles représentent 22 ha par exploitation, soit 11% de la SAU (45% au maximum). Or, elles représentent aussi 56% des surfaces en miscanthus. On en déduit qu'en moyenne le miscanthus est préférentiellement implanté sur des parcelles marginales, mais qu'il ne s'agit pas d'une condition générale à l'adoption du miscanthus. Les raisons évoquées par les agriculteurs pour expliquer le caractère marginal des parcelles sont le plus souvent la qualité du sol (granulométrie, cailloux, profondeur, hydromorphie ou caractère séchant), l'éloignement par rapport aux bâtiments principaux de l'exploitation, puis la petite taille. Une forme irrégulière, une proximité avec des bois ou des habitations, et une localisation enclavée sont d'autres raisons souvent évoquées. Notons que la plupart des parcelles marginales cumulent plusieurs de ces raisons (53% deux raisons et 10% trois raisons, les agriculteurs évoquant une raison unique pour seulement 37% des parcelles marginales en miscanthus).

Dans la zone étudiée, le miscanthus est donc préférentiellement cultivé sur des parcelles marginales, après un gel permanent, ce qui est un signe positif pour le bilan environnemental de cette culture, et le problème de sa compétition avec les productions alimentaires. Néanmoins, une part importante du miscanthus est cultivée à la place de cultures traditionnelles (67% des surfaces) et/ou sur des terres non marginales (44%). De plus, cette part est susceptible

Tableau 2.3 – Caractéristiques des parcelles de miscanthus

	Surface cumulée		Obs.
	ha	%	
Parcelles marginales, dont[a]:	164	56	79
qualité du sol	105	36	46
éloignement	86	30	28
taille	61	21	50
pente	3	1	2
forme	48	16	23
autre	158	54	55
Parcelles non marginales	128	44	44
Total	292	100	123

[a] Une même parcelle est le plus souvent marginale pour plusieurs raisons à la fois.

d'augmenter avec la diffusion du miscanthus et l'accroissement des surfaces par exploitation.

2.2 Conditions économiques

Dans cette section, nous nous nous intéressons aux conditions économiques qui prévalent en Bourgogne relativement à la culture de miscanthus.

2.2.1 Contrats de production et financement privé

Les herbacées pérennes énergétiques présentent trois attributs originaux : ce sont des cultures innovantes, commercialisées sur un marché emergent, et dont le cycle de production est particulièrement long. Le premier effet de ces trois caractéristiques en cas d'adoption d'une herbacée pérenne est la production de revenus très aléatoires, comparativement à ceux issus d'une activité traditionnelle telle que le blé. Cet effet risque, noté (E1), est décomposé dans le Tableau 2.4 en sous-effets (E1.1), (E1.2), (E1.3) selon le type de risque concerné. La longueur du cycle de production a deux autres effets : (E2) un décalage des recettes dans le temps par rapport aux coûts initiaux, ce qui pèse sur la rentabilité annuelle [15], et (E3) un besoin de liquidités au moment de la plantation (3 200 € HT par hectare de frais d'implantation). [16]

15. Dans le Chapitre 1, nous montrons que le panic érigé et le miscanthus sont moins rentables en termes de valeur actuelle nette (VAN) qu'une rotation céréalière. Monti et al. (2007) et Deverell et al. (2009) présentent des résultats comparables.
16. Source : Société Bourgogne Pellets.

Tableau 2.4 – Effets potentiels sur les exploitations de l'adoption des herbacées pérennes (sans contrat de production) en remplacement d'une culture céréalière traditionnelle

Effet	Attributs de la culture pérenne à l'origine de l'effet	Impact de l'effet sur l'adoption *a priori*
E1 augmentation du risque revenu au niveau de la parcelle		-
E1.1 augmentation du risque prix	marché émergent/longueur du cycle de production	-
E1.2 augmentation du risque technique	culture innovante	-
E1.3 augmentation du risque coût	longueur du cycle de production	-
E2 diminution du revenu moyen (VAN)	longueur du cycle de production	-
E3 besoins de trésorerie	longueur du cycle de production	-
E4 diminution du risque rendement	rusticité/absence de maladies et ravageurs	+
E5 diminution du temps de travail	extensivité	+
E6 bénéfices environnementaux	extensivité/couverture hivernale	+

Pour réduire ces effets négatifs sur l'attractivité du miscanthus pour les agriculteurs, les transformateurs (ou intermédiaires commerciaux) proposent dans la plupart des cas des contrats de production. [17] Les systèmes les plus courants sont un prix d'achat garanti sur le long terme, une assistance technique, et/ou des facilités de financement pour la plantation. [18]

C'est le cas dans la zone d'étude. Les deux coopératives de déshydratation s'engagent en effet à acheter la production de miscanthus sur la durée de la plantation à un prix minimum de 70 €/t de matière sèche, et proposent un suivi technique. [19] Pour les premiers agriculteurs s'étant engagé dans de tels contrats, les coopératives ont en plus offert la totalité des frais de plantation, mais cette disposition exceptionnelle concerne seulement deux agriculteurs de notre échantillon. En ce qui concerne les facilités de financement, seul le contrat proposé par Aiserey prévoit un dispositif spécifique : les agriculteurs dépendant de l'usine d'Aiserey (45 adoptants sur 59) bénéficient d'une avance de trésorerie portant sur la moitié des coûts de plantation, sans frais et remboursable sur 5 ans. Pour compléter le financement de la plantation, les agriculteurs peuvent avoir recours au crédit bancaire, en particulier lorque les surfaces concernées sont importantes. Dans l'échantillon, 3 agriculteurs seulement ont contracté un crédit bancaire, 2 du bassin d'Aiserey (8 et 12 ha de miscanthus) et 1 du bassin de Baigneux (6 ha).

17. Il s'agit aussi d'un moyen pour les industriels de sécuriser leur approvisionnement en matière première.
18. Voir (Bocquého, 2008, p.36–37) pour la description d'autres types de contrats et mécanismes de partage des risques rencontrés en France pour la production de cultures pérennes énergétiques.
19. La coopérative d'Aiserey dispose de moyens supplémentaires pour le suivi technique et la communication autour du miscanthus.

Tableau 2.5 – Types de contrat rencontrés dans la zone d'étude

Type de contrat	Prix garanti à long terme	Appui technique et communication	Financement des coûts de plantation	Stockage de la production
Aiserey	15 ans	++	avance de trésorerie	agriculteur
Aiserey bis	15 ans	++	offerts	agriculteur
Baigneux	15 ans	+	aucun	coopérative
Baigneux bis	15 ans	+	offerts	coopérative
Effet impacté	risque prix	risque technique	revenu moyen (VAN)/besoins de trésorerie	besoins de capacité de stockage

Il existe d'autres différences annexes entre les deux contrats. Dans le cas de Baigneux-les-Juifs (14 adoptants), l'accord est le plus souvent oral, et le miscanthus est enlevé juste après la récolte. Ce dernier point augment légèrement le revenu espéré et desserre la contrainte de la capacité de stockage. [20] En revanche, dans le cas d'Aiserey, le contrat fait l'objet d'une formalisation écrite et le stockage est pris en charge par les agriculteurs. Les caractéristiques des différents types de contrats rencontrés sont résumées dans le Tableau 2.5.

Dans le Tableau 2.6, les adoptants de l'échantillon sont répartis selon le type de contrat reçu. La forme des contrats pourrait avoir un effet significatif sur les surfaces allouées en moyenne au miscanthus mais nos données ne permettent pas de conclure. En effet, comme chaque coopérative propose un seul grand type de contrat, l'effet contrat est confondu avec l'effet bassin. Or, l'effet bassin est aussi susceptible d'influencer de manière importante les surfaces d'adoption car les conditions pédo-climatiques autour de chacun des sites d'Aiserey et Baigneux-les-Juifs sont très différentes (plaine de la Saône fertile dans le premier cas, et plateaux calcaires de Bourgogne plus froids dans le second). Les effets contrat et pédo-climat ne peuvent donc pas être dissociés. De plus, plusieurs caractéristiques variant simultanément d'un contrat à l'autre, il est impossible d'évaluer indépendamment les effets de chacune d'entre elles sur les surfaces en miscanthus.

2.2.2 Aides publiques

Les aides publiques accordées aux producteurs de biomasse lignocellulosique sont très variables dans l'espace et dans le temps. Le seul dispositif commun, l'aide couplée aux Cultures

20. Le problème du stockage de la récolte peut être critique dès lors que les exploitations dépassent une certaine production. D'une part, le produit récolté est peu dense et, d'autre part, la récolte est concentrée en fin d'hiver alors que l'approvisionnement des unités de transformation en énergie doit être continue.

Energétiques (ACE), a été mis en place au niveau européen en 2004 et a été supprimé en 2010. [21] Il a été jugé peu incitatif et peu justifié environnementalement car il concernait l'ensemble des cultures énérgétiques, y compris celles destinées aux biocarburants de première génération.

Dans l'échantillon, 80% des surfaces en miscanthus ont été plantées en 2009 et 2010. Les agriculteurs ont donc peu bénéficié de l'ACE. Par contre, depuis 2009, la zone étudiée profite de mesures de diversification dans le cadre du Programme de Restructuration National (PRN) du secteur sucrier et betteravier, un programme qui soutient notamment le développement d'une filière miscanthus. Pour beaucoup d'agriculteurs betteraviers, le miscanthus a donc constitué une culture de reconversion. Les bénéficiaires ont reçu une subvention à l'implantation à hauteur d'au moins 40% des dépenses éligibles entre 2009 et 2011. [22] En réduisant de manière significative les coûts d'implantation, cette aide spécifique a répondu aux difficultés de trésorerie potentielles des agriculteurs, tout en améliorant la rentabilité globale du miscanthus. Parmi les adoptants de l'échantilllon, 88% ont bénéficié de la subvention à l'implantation du PRN. Etonnamment, un seul producteur a déclaré avoir perçu l'ACE, ce qui confirme le faible pouvoir incitatif de cette dernière aide.

Dans le Tableau 2.6, les adoptants de l'échantillon sont répartis selon le bassin auxquels ils appartiennent et les financements reçus (aide publique PRN ou contrats couvrant totalement les frais d'implantation). [23] On constate que les producteurs qui n'ont pas bénéficié de la subvention du PRN (plantations antérieures à 2009) ont des surfaces de miscanthus très inférieures à la moyenne (moins de 1,5 ha contre 4,9 ha). La subvention semble donc très incitative et influencer les surfaces alloueés au miscanthus dans les exploitations.

21. L'ACE valait en 2010 45 €/ha/an, dans la limite d'un plafond de 2 millions d'hectares pour les 27 Etats-membres. Voir Bocquého (2008) pour des détails sur l'ACE et l'aide Jachère Industrielle.

22. Ce taux est porté à 50% en zone défavorisée. Lorsqu'il s'agit d'un jeune agriculteur, une majoration supplémentaire de 10 points est appliquée, portant le taux à 50% en zone non défavorisée et 60% en zone défavorisée. Le montant des investissements doit être compris entre 1 600 et 70 000 €(ce qui correspond à une surface de miscanthus comprise entre 0,5 et 22 ha environ) (Source : Document régional du PRN, Bourgogne et Franche-Comté, consultable à : http://draaf.bourgogne.agriculture.gouv.fr/Document-regional-du-programme-de).

23. Lorsque les producteurs ont planté du miscanthus en plusieurs fois dans des conditions différentes, les conditions les plus avantageuses seulement sont reportées (contrat « standard » > contrat « bis » et aide PRN > pas d'aide PRN).

Tableau 2.6 – Aides reçues et types de contrats signés par les adoptants

Bassin	Aide PRN	Pas d'aide PRN		Total
		contrat standard	contrat « bis »	
Aiserey	44	0	1	45
	(5,7)	(0)	(2,7)	(5,6)
Baigneux	8	5	1	14
	(4,0)	(1,5)	(0,2)	(2,8)
Total	52	5	2	59
	(5,4)	(1,5)	(1,4)	(4,9)

Surfaces de miscanthus entre parenthèses (en ha).

2.2.3 Anticipations sur la conjoncture économique

Le Tableau 2.7 donne des indications sur les scénarios économiques que les agriculteurs jugent les plus probables à moyen terme. Les deux premières lignes notent sur 5 points la probabilité de mesures spécifiques pour les cultures lignocellulosique de la part de la Politique Agricole Commune (PAC) et d'une augmentation de la demande en biomasse-énergie. Les deux dernière lignes donnent une tendance pour le prix du blé et le prix des carburants d'origine fossile (diminution, augmentation, ou stagnation).

Les scores obtenus montrent que les agriculteurs sont plutôt pessimistes à propos d'un soutien de la PAC (score moyen de 2,6, soit entre « peu probable » et « moyennement probable ») et plutôt optimistes à propos de l'évolution de la demande en biomasse-énergie (score moyen de 3,8, soit proche de « probable »). Seule la probabilité de l'augmentation de la demande en biomasse-énergie est évaluée différemment par les adoptants et les non adoptants (test d'égalité des moyennes rejeté au seuil de 5%). Comme attendu, les premiers sont plus optimistes que les seconds.

En ce qui concerne les prix du blé et du fioul, les agriculteurs prévoient en moyenne une légère augmentation. Il n'y a pas de différence significative entre adoptants et non adoptants.

Tableau 2.7 – Anticipations des agriculteurs sur le contexte économique

	Echantillon total[c]			Non adoptants			Adoptants			Δ_{A-NA}[d]
	Moy.	E.-T.	Obs.	Moy.	E.-T.	Obs.	Moy.	E.-T.	Obs.	Moy.
Futur soutien PAC spécifique aux cultures lignocellulosiques[a]	2,6	1,3	107	2,6	1,4	49	2,7	1,2	58	−0,1
Augmentation demande biomasse-énergie[a]	3,8	1,2	111	3,7	1,3	52	4,2	0,9	59	−0,5**
Tendance prix blé[b]	0,6	0,6	105	0,6	0,6	50	0,5	0,6	55	0,1
Tendance prix carburant fossile[b]	0,8	0,4	110	0,7	0,4	51	0,8	0,4	59	−0,1

[a] La probabilité de chaque événement est évaluée sur une échelle de 1 à 5 (1=pas du tout probable, 5=tout à fait probable). La formulation exacte de la question posée figure dans l'Annexe F (question 62.).
[b] La tendance des prix est évaluée sur une échelle à 3 points (-1=diminution, 0=stagnation, 1=augmentation). La formulation exacte de la question posée figure dans l'Annexe F (questions 63. et 64.).
[c] Statistiques pondérées. [d] Différence Adoptants-Non adoptants : *, ** et *** indiquent une seuil de significativité à 10, 5 et 1% respectivement.

2.3 Perceptions des agriculteurs à propos de l'activité miscanthus

Dans cette section, nous évaluons les perceptions des agriculteurs quant aux effets du miscanthus sur leur activité de production.

2.3.1 Effets caractéristiques

Dans le Tableau 2.4 nous décrivons les huit effets principaux (E1.1 à E6) sur les exploitations d'une production d'herbacées pérennes énergétiques. Les effets E1.1 à E3 sont des effets *a priori* positifs pour l'attractivité de ces nouvelles cultures, et les effets E6 à E8 *a priori* positifs. Ce sont des effets objectifs établis à partir de l'information scientifique actuellement disponible. Cependant, la diffusion de cette information auprès des agriculteurs est probablement partielle car les herbacées pérennes énergétiques sont des cultures encore peu connue. Or, les décisions que prennent les agriculteurs dépendent de l'information à laquelle ils ont eu accès. Il est donc important de vérifier que les effets notables tels que reportés dans le Tableau 2.4 concordent avec les propres perceptions des agriculteurs.

Dans le Tableau 2.8 figure le degré d'adéquation moyen des agriculteurs de Bourgogne avec des propositions correspondant aux effets E1.1, E1.2 et E2 à E8. Un score élevé (>3) indique un degré d'accord élevé, sauf pour les propositions correspondant aux effets E2 et E4 qui sont formulées en opposition. Les colonnes 1–3 concernent l'échantillon total, les colonnes 4–6 le sous-échantillon des non adoptants, et les colonnes 7–9 le sous-échantillon des adoptants. Les réponses suggèrent trois résultats principaux.

Premièrement, dans l'échantillon total, les scores moyens des propositions correspondant à E1.1 (forte incertitude de débouchés en l'absence de contrat), E1.2 (appui technique), E3 (investissement initial élevé), E5 (gain de temps) et E6 (bénéfices environnementaux) sont supérieurs à 3, et celui correspondant à E2 (rentabilité par rapport à une rotation traditionnelle) est inférieur à 3. Les perceptions des agriculteurs sont donc compatibles avec six des huit effets listés en introduction. En revanche, le score moyen de la proposition correspondant à E4 (forte incertitude rendements) est supérieur à 3, ce qui signifie que les agriculteurs perçoivent une forte incertitude sur les rendements du miscanthus, contrairement à ce qui était attendu. Cependant, les effets listés en introduction sont des effets relatifs alors que les propositions expriment des effets absolus. Pour invalider E4, il faudrait en fait que les agriculteurs perçoivent un risque de production plus important sur le miscanthus que sur les cultures alternatives. Nous verrons dans la section suivante que ce n'est pas le cas.

Deuxièmement, les réponses donnant les scores les plus éloignés du score neutre de 3 sont les propositions correspondant aux effets E1.1 (forte incertitude débouchés en l'absence de contrats) et E3 (investissement initial élevé). De plus, ce sont aussi les scores avec les écart-types (E.-T.) les plus faibles. Ces deux effets semblent donc à la fois les plus marqués et les plus consensuels. Nous verrons au Chapitre 1 comment les contrats de production proposés aux agriculteurs permettent de limiter ces effets négatifs.

Troisièmement, les réponses des agriculteurs adoptants diffèrent des réponses des non adoptants dans le sens attendu : les effets positifs sont exacerbés et les effets négatifs minimisés.[24] Un test d'égalité des moyennes montre que les différences significatives sont celles relatives à, dans l'ordre, la rentabilité (E2, valeur p=0,039), le risque débouchés (E1.1, valeur p=0,040), le risque rendement (E4, valeur p=0,041) et les bénéfices environnementaux (E6, valeur p=0,000). Ce résultat peut s'interpréter de deux manières, économique et psychologique. Soit ce sont des

24. Excepté pour les propositions correspondant à E1.2 (appui technique) et E5 (gain de temps) mais la différence n'est pas significative (test d'égalité des moyennes non rejeté).

Tableau 2.8 – Caractéristiques du miscanthus telles que perçues par les agriculteurs

	Echantillon total[a]			Non adoptants			Adoptants			Δ_{A-NA}[b]
	Moy.	E.-T.	Obs.	Moy.	E.-T.	Obs.	Moy.	E.-T.	Obs.	Moy.
Forte incertitude débouchés en l'absence de contrat (E1.1)	4,5	1,0	109	4,5	0,9	50	4,1	1,2	59	0,4**
Appui technique (E1.2)	3,3	1,3	107	3,3	1,3	48	3,5	1,3	59	−0,2
Rentable comparé à rotation traditionnelle (E2)	2,6	1,2	72	2,4	1,2	26	3,0	1,0	46	−0,6**
Investissement initial élevé (E3)	4,6	0,8	107	4,6	0,8	48	4,5	0,9	59	0,0
Forte incertitude rendements (E4)	4,0	1,1	100	4,1	1,1	42	3,6	1,4	58	0,5**
Gain temps significatif (E5)	3,8	1,3	109	3,9	1,3	50	3,5	1,6	59	0,3
Bénéfique pour l'environnement (E6)	3,7	1,1	105	3,6	1,1	47	4,3	0,7	58	−0,7***

Chaque proposition est évaluée dans les conditions de production de l'agriculteur (sauf mention contraire) sur une échelle de Likert de 1 à 5 (1=pas du tout d'accord, 5=tout à fait d'accord). On demande aux non adoptants de prendre en compte les conditions économiques de la région (contrat de production et aide PRN). La formulation exacte de la question posée figure dans l'Annexe F (question 52.).
[a] Statistiques pondérées. [b] Différence Adoptants-Non adoptants : *, ** et *** indiquent une seuil de significativité à 10, 5 et 1% respectivement.

effets qui influencent fortement l'adoption (la rentabilité et les bénéfices environnementaux positivement, les deux types de risque négativement), et les agriculteurs dont les conditions de production favorisent les effets positifs (par exemple plus de terres marginales à valoriser ce qui améliore la rentabilité relative) et limitent les effets négatifs (par exemple meilleure information sur les marchés et les rendements) voient le miscanthus comme plus attractif, et ont donc davantage tendance à l'adopter. Soit les agriculteurs adoptants sont plus optimistes que les non adoptants : ils croient davantage à la rentabilité et aux bénéfices environnementaux du miscanthus, et perçoivent moins de risques.

2.3.2 Effet risque

Nous avons vu que le caractère risqué d'une innovation était susceptible d'être un frein important à son adoption, surtout en début de diffusion (manque de références agronomiques, marché emergent). Les résulats précédents l'ont confirmé dans le cas du miscanthus en Bourgogne pour deux types de risque : les agriculteurs non adoptants perçoivent un risque de production et un risque de débouchés élevés sur le miscanthus. Comme les agriculteurs adoptants perçoivent un risque significativement inférieur, il est vraisemblable que le risque soit déterminant dans l'adoption : un faible risque perçu augmenterait la probabilité d'adoption.

Dans cette section, nous proposons une analyse plus fine des risques perçus par les agriculteurs. D'une part, nous proposons une comparaison avec le risque perçu sur le blé car une innovation est évaluée en comparaison avec les activités concurrentes. D'autre part, nous considérons d'autres types de risque que le risque rendement et le risque de débouchés. De plus, afin de ne pas répéter les résultats obtenus dans la section précédente, nous proposons aux agriculteurs de noter le risque débouchés en présence des contrats à long terme en vigueur en Bourgogne (décrits à la Section 2.2.1).

Le Tableau 2.9 donne les scores correspondant à l'importance que donnent les agriculteurs à 16 différents types de risque, dans le cadre des activités miscanthus et blé tendre. Les statistiques du blé figurent en termes relatifs par rapport au miscanthus (différence miscanthus - blé Δ_{M-B}). A nouveau, les réponses des adoptants et des non adoptants sont distinguées.

En ce qui concerne les scores moyens du miscanthus dans l'échantillon total, on obtient pour tous les grands types de risque (production, technique, marché, économique, institutionnel) des valeurs proches de 2 en moyenne (risque « peu important »). Le risque de marché correspond à la fois au score moyen et à l'écart-type les plus élevés (2,9 et 1,4 respectivement), notamment à cause du risque de débouchés (score moyen de 3,1), et ce malgré la prise en compte des contrats à long terme.

A l'opposé, le risque de production correspond au score et à l'écart-type les plus faibles (2,0 et 0,6 respectivement). Ce résultat semble contredire l'observation faite dans la section précédente, c'est-à-dire des agriculteurs « plutôt d'accord » avec l'existence d'une forte incertitude sur les rendements du miscanthus. Cependant, il est difficile de comparer des scores obtenus avec des questions aux formulations et aux échelles différentes (terme *risque* et échelle d'importance contre terme *incertitude* et échelle de Likert).

En ce qui concerne la différence miscanthus-blé (Δ_{M-B}), plus pertinente que des scores absolus lorsque deux activités sont en concurrence, on constate qu'en moyenne les grands types de risque sont perçus comme inférieurs sur le miscanthus par rapport au blé, sauf le risque institutionnel (différence de score moyenne de +0,5). Le plus grand écart concerne le risque de production (-1,1) et le plus petit le risque technique (-0,2). L'hypothèse selon laquelle le miscanthus diminue le risque de rendement de l'agriculteur (E4) est donc finalement cohérente avec les perceptions des agriculteurs.

L'observation des score moyens dans l'échantillon total donne un autre résultat important : il existe des risques spécifiques au miscanthus (score moyen assez élevé et $\Delta_{M-B} > 0$). C'est le cas du risque de débouchés, du risque de dégradation de la valeur de la parcelle, du risque des relations avec le bailleur, et du risque de contrepartie. Ce sont tous des risques peu probables mais dont les effets (négatifs) en termes de revenu peuvent être très importants. On fait l'hypothèse que la distribution de probabilités des revenus issus du miscanthus corresponde à une courbe en cloche (loi normale par exemple). Ces événements extrêmement défavorables mais peu probables composeraient alors la queue gauche de la distribution. Nous verrons dans le Chapitre 3 (Section 3.6) que les individus (y compris les agriculteurs) donnent généralement beaucoup de poids à de tels événements. Les scores présentés ici rendent probablement compte de cette attitude.

Par ailleurs, les scores moyens des grands types de risque par sous-échantillon montrent que les agriculteurs adoptants perçoivent les risques économique et institutionnel comme significativement inférieurs à ceux perçus par les non adoptants (au seuil de 1%). On retrouve trois des quatre événements extrêmes listés dans le paragraphe précédent comme éléments explicatifs (dégradation de la valeur de la parcelle, relations bailleur, contrepartie du contrat). La même observation avait été faite dans la section précédente pour l'incertitude sur les rendements et les débouchés. Cela renforce l'idée que les événements extrêmes spécifiques au miscanthus sont probablement déterminants dans le processus d'adoption du miscanthus.

Enfin, l'observation des scores relatifs par sous-échantillon suggère que l'écart miscanthus-blé se creuse chez les adoptants pour ces mêmes risques économique et institutionnel (différence significative au seuil de 1%), ainsi que pour le risque de marché (différence significative au seuil de 5%) . L'écart Δ_{M-B} qui est positif chez les adoptants (miscanthus plus risqué que le blé ou équivalent) devient négatif chez les non adoptants (miscanthus moins risqué que le blé). A nouveau, les quatre événements extrêmes sont impliqués. Cela s'explique par le fait que ces risques spécifiques n'existent pas sur le blé, et donc que toute variation du score absolu du miscanthus entre adoptants et non adoptants est totalement répercutée dans le score relatif.

2.4 Conclusion

Dans ce chapitre nous avons caractérisé la production de miscanthus en Bourgogne, une région dans laquelle la diffusion de la nouvelle culture est récente et rapide. Les données sont issues d'une enquête menée auprès de 111 agriculteurs, 59 producteurs de miscanthus et 52 non producteurs. Nous obtenons trois sortes de résultats.

Premièrement, nous montrons que le miscanthus a deux atouts en termes de durabilité. D'une part, sa conduite est très extensive, les intrants chimiques utilisés se limitant à partir de la troisième année à des apports de phosphate et de potassium. D'autre part, le miscanthus est planté de préférence sur des parcelles marginales peu rentables (56% des surfaces implantées), et plus particulièrement sur celles en gel permanent. Sherrington et al. (2008) remarqua un comportement similaire chez les producteurs de saule en courte rotation et de miscanthus au Royaume-Uni. Cependant, 66% des surfaces implantées succèdent à des rotations de cultures, ce qui suggère une réelle concurrence avec les usages alimentaires des sols. Dans le futur, ce dernier chiffre pourrait diminuer si la réglementation autorisait l'implantation de cultures pérennes énergétiques sur les bandes enherbées le long des cours d'eau. Il pourrait au contraire augmenter si, comme l'anticipent les agriculteurs, le marché de la biomasse-énergie offrait plus de débouchés ou la PAC offrait un soutien spécifique indépendant de la localisation de la culture.

Deuxièmement, nous décrivons les dispositifs actuellement proposés aux agriculteurs pour réduire le risque associé au miscanthus, diminuer les besoins en trésorerie et augmenter la rentabilité moyenne de la culture. Les contrats de production offerts par les transformateurs constituent le premier dispositif. En garantissant un débouché à long terme, à un prix minimum, et en apportant un soutien technique, ces contrats diminuent très fortement l'exposition au risque des agriculteurs. Certains contrats proposent également une avance de trésorerie pour financer la période d'établissement de la culture. Les subventions à l'implantation offertes par les pouvoirs publics constituent le second dispositif. Ces subventions jouent sur les trois leviers à la fois : diminution du risque, relâchement de la contrainte de trésorerie, augmentation de la rentabilité. Ces deux dispositifs ont pour objectif de développer l'offre globale de biomasse-énergie sans tenir compte des changements d'usage des sols provoqués. Les contrats à long terme et subventions à

Tableau 2.9 – Risques perçus par les agriculteurs sur l'activité miscanthus

	Echantillon total[a]			Non adoptants			Adoptants			Δ_{A-NA}[c]
	Moy.	E.-T.	Obs.	Moy.	E.-T.	Obs.	Moy.	E.-T.	Obs.	Moy.
Risque de production[b]	2,0	0,6	106	2,0	0,6	47	2,1	0,7	59	−0,1
$\boldsymbol{\Delta_{M-B}}$[b]	−1,1	1,0	106	−1,1	1,0	47	−1,2	0,9	59	0,1
maladie	1,3	0,5	88	1,2	0,4	33	1,3	0,6	55	−0,0
Δ_{M-B}	−2,5	1,1	88	−2,6	1,1	33	−2,3	1,3	55	−0,3
ravageurs	2,3	1,1	88	2,3	1,1	35	2,2	1,2	53	0,1
Δ_{M-B}	−0,6	1,8	88	−0,5	1,8	35	−0,6	1,7	53	0,1
accident climatique	2,0	1,0	99	2,0	1,0	42	2,2	1,1	57	−0,2
Δ_{M-B}	−1,8	1,2	99	−1,8	1,2	42	−1,9	1,2	57	0,1
mauvaises herbes	2,0	1,1	104	1,9	1,1	45	2,5	1,3	59	−0,7***
Δ_{M-B}	−1,4	1,7	104	−1,5	1,7	45	−1,0	1,7	59	−0,6*
incendie	2,2	1,3	102	2,3	1,3	43	2,0	1,3	59	0,3
Δ_{M-B}	0,0	1,5	102	0,1	1,5	43	−0,4	1,4	59	0,6*
Risque technique[b]	2,2	0,9	105	2,2	0,9	46	2,3	1,0	59	−0,1
$\boldsymbol{\Delta_{M-B}}$[b]	−0,2	0,9	105	−0,2	0,8	46	−0,3	1,1	59	0,0
conduite ou récolte	2,0	0,9	101	1,9	0,8	42	2,3	1,2	59	−0,4*
Δ_{M-B}	−1,2	1,3	101	−1,2	1,2	42	−1,0	1,5	59	−0,2
choix parcelle	2,4	1,3	103	2,5	1,3	46	2,4	1,2	57	0,1
Δ_{M-B}	0,6	1,1	103	0,7	1,1	46	0,5	1,2	57	0,1
Risque de marché[b]	2,9	1,4	102	3,0	1,5	43	2,5	1,0	59	0,4*
$\boldsymbol{\Delta_{M-B}}$[b]	−0,0	1,6	102	0,1	1,7	43	−0,7	1,1	59	0,8**
prix output	2,6	1,6	91	2,7	1,7	34	2,1	1,2	57	0,6*
Δ_{M-B}	−1,6	1,7	91	−1,5	1,8	34	−1,9	1,6	57	0,4
débouchés	3,1	1,5	99	3,1	1,6	41	2,9	1,4	58	0,2
Δ_{M-B}	1,0	1,7	99	1,1	1,7	41	0,5	1,5	58	0,6*
Risque économique[b]	2,2	0,9	106	2,3	1,0	47	1,8	0,7	59	0,5***
$\boldsymbol{\Delta_{M-B}}$[b]	−0,0	1,1	106	0,1	1,1	47	−0,5	0,8	59	0,6***
coûts production	1,9	1,1	100	2,0	1,2	41	1,6	0,8	59	0,5**
Δ_{M-B}	−1,9	1,3	100	−1,8	1,4	41	−1,9	1,1	59	0,1
coûts main d'œuvre	1,7	0,8	52	1,8	0,9	18	1,6	0,7	34	0,2
Δ_{M-B}	−0,1	1,0	52	0,0	1,0	18	−0,4	1,0	34	0,4
coûts crédit	2,2	1,4	51	2,3	1,5	24	1,7	1,0	27	0,6
Δ_{M-B}	0,3	1,3	51	0,4	1,3	24	−0,3	1,0	27	0,7**
valeur parcelle	2,9	1,6	98	3,0	1,6	43	2,4	1,4	55	0,6*
Δ_{M-B}	1,7	1,6	98	1,9	1,6	43	1,1	1,4	55	0,8**
Risque institutionnel[b]	2,5	1,0	108	2,6	1,0	49	2,0	0,9	59	0,6***
$\boldsymbol{\Delta_{M-B}}$[b]	0,5	1,1	108	0,7	1,0	49	−0,3	1,1	59	1,0***
relations bailleur	3,0	1,5	85	3,1	1,5	47	2,5	1,5	38	0,7**
Δ_{M-B}	2,0	1,5	85	2,1	1,5	47	1,3	1,5	38	0,8**
normes environnementales	1,8	1,1	102	1,8	1,2	43	1,5	1,0	59	0,3
Δ_{M-B}	−1,5	1,6	102	−1,4	1,6	43	−1,9	1,4	59	0,5
contrepartie du contrat	2,6	1,4	102	2,7	1,5	43	2,2	1,3	59	0,5*
Δ_{M-B}	1,0	1,6	100	1,2	1,6	43	0,5	1,4	57	0,7**

L'importance de chaque risque est évalué dans les conditions de production de l'agriculteur sur une échelle de 1 à 5 (1=pas important du tout, 5=très important). Le score du miscanthus est comparé au score du blé tendre pour chaque risque (Δ_{M-B}). La formulation exacte de la question posée figure dans l'Annexe F (question 51.).

[a] Statistiques pondérées. [b] Moyenne des scores sur l'ensemble des sous-types de risque. [c] Différence Adoptants-Non adoptants : *, ** et *** indiquent une seuil de significativité à 10, 5 et 1% respectivement.

l'implantation sont deux dispositifs couramment utilisés, en France (Bocquého, 2008; Feuga, 2010) mais aussi dans d'autres pays comme le Royaume-Uni (Sherrington et al., 2008) ou les Etats-Unis (Alexander et al., 2011).

Troisièmement, nous évaluons les perceptions des agriculteurs à propos des effets du miscanthus sur leur exploitation, en distinguant producteurs de miscanthus et non-producteurs. Les effets les plus marqués et les plus consensuels sont la forte incertitude sur les débouchés en l'absence de contrat (risque prix) et les besoins en trésorerie pour l'investissement initial. Ceci justifie l'usage général des contrats de production et de mécanismes de financement pour développer la culture des espèces pérennes énergétiques. D'ailleurs, en présence de contrats long terme, les agriculteurs perçoivent le miscanthus comme globalement moins risqué qu'une culture concurrente comme le blé tendre. Cependant, des risques extrêmement défavorables mais peu probables subsistent sur le miscanthus, comme une erreur dans le choix de la parcelle conduisant à un échec de l'implantation, une dégradation de la valeur de la parcelle ou un risque de retrait de l'acheteur du contrat de production. Sherrington et al. (2008) au Royaume-Uni et Alexander et al. (2011) aux Etats-unis relèvent clairement l'inquiétude des agriculteurs par rapport à ce dernier risque, dit de contrepartie.

Ces résultats confirment que la sensibilité des agriculteurs au risque et au temps doivent jouer un rôle important dans l'adoption des cultures pérennes énergétiques par les agriculteurs. Ils suggèrent que ce rôle dépend du type de contrats proposé aux agriculteurs pour produire la biomasse. C'est ce que nous avons montré de manière normative au Chapitre 1. Ils suggèrent également qu'un cadre théorique incluant la sensibilité aux événements extrêmes tel que la théorie des perspectives (Kahneman and Tversky, 1979) pourrait être pertinent. Dans le Chapitre 3 nous mesurons les préférences individuelles des agriculteurs par rapport au risque dans ce cadre théorique. Dans le Chapitre 4 nous estimons l'impact des préférences par rapport au risque sur l'adoption, ainsi que l'impact des préférences par rapport au temps.

Chapter 3

Expected utility or prospect theory maximisers? Results from a structural model based on field-experiment data.

We elicit the risk preferences of a sample of French farmers in a field-experiment setting considering both expected utility theory (EUT) and cumulative prospect theory (CPT). With EUT, our results show that farmers are characterised by a concave utility function which implies risk aversion. The CPT model confirms this result but provides the additional information that they are also loss averse. Moreover, under CPT farmers exhibit an inverse S-shaped probability weighting function, meaning that they tend to overweight extreme events and low probabilities, while underweighting high probabilities. Overall, under the given conditions, CPT explains farmers' behaviour more fully than EUT, further evidence challenging the use of EUT in all cases. Moreover, we investigate how preferences correlated with individual farmer and farm characteristics. We review the implications for research into farmers' behaviour when faced with risk, which is crucial when it comes to encouraging innovations and covering risks for example. Policy makers and companies should differentiate the behaviour of farmers according to gains and losses as well as take into greater consideration extreme events.

Keywords: risk preferences, experimental economics, loss aversion, probability weighting, France
JEL Codes: C93; D81; Q12

3.1 Introduction

For decades, risk has been a central feature of studies in the field of agricultural economics because it is intrinsic to agricultural production, and it plays a key role in the major decisions farmers are making every day. Risk has been shown to be a crucial element in understanding crop diversification (Serra et al., 2009), choices of contracts (Zheng et al., 2008; Dubois and Vukina, 2009), uses of weather or revenue insurance (Mahul, 2003; Coble, 2004) or attempts to adopt innovations (Abadi Ghadim et al., 2005; Kallas et al., 2010).

Since differences in farmers' willingness to take risks can induce different agricultural decisions, understanding individual attitudes toward risk is tightly linked to the goal of analysing and understanding the economic behaviour of farmers. As a result, a lot of effort has been devoted to identify farmer's risk preferences using reliable direct methods. In experimental methods, risk attitudes are elicited from real choices between lotteries (see the seminal papers by Binswanger (1980) or Binswanger (1981)). In revealed preference methods, risk preferences are imputed based on the divergence between observed farmer's decisions (input use, output choice) and optimal decisions under risk (see Antle, 1987, 1989; Chavas and Holt, 1996).

Although the two methods strongly differ in terms of underlying assumptions, they do have in common the fact that farmers are assumed usually to be expected utility maximisers according to expected utility theory (EUT) developed by von Neumann and Morgenstern (1947).[1] There are two reasons explaining why EUT has been highly used in agricultural economics. First, EUT makes possible to separate risk exposure, measured by a (possibly subjective) probability distribution, from preferences over outcomes, represented by a utility function (Chavas et al., 2010). A second reason is the ease with which it can be applied, coupled with the lack of a strongly appealing alternative (Just and Peterson, 2010).

However, the dominance of EUT in agricultural economics is surprising for several reasons. First, since the work of Allais (1953), psychologists and economists have provided substantial evidence that individuals do not necessarily behave according to many of the key assumptions underlying EUT, and indeed, their behaviour seems to deviate from the model in predictable and systematic ways. EUT has for instance been shown to provide implausible values of risk aversion

1. Exceptions include recent studies by Harrison et al. (2010), Humphrey and Verschoor (2004b), Liu (2010), Galarza (2009) or Pennings and Smidts (2003) about farmers and by Nguyen and Leung (2009) or Tanaka et al. (2010) about rural households.

(Rabin, 2000). It is well known that with EUT the degree of risk aversion in the case of small stakes is wholly inconsistent with the degree of risk aversion in the case of high stakes. Second, a large number of theories which are now available as alternatives to EUT (Starmer, 2000) have identified some key factors, such as reference dependence and probability weighting, explaining why EUT predictions do not fully match reality. Third, over the last few years, empirical testing of EUT against non-expected utility alternatives has provided evidence favouring the latter (Loomes et al., 2002; Tanaka et al., 2010; Mason et al., 2005).[2] Fourth, some characteristics of non-expected utility theories fit the agricultural economics context particularly well. On the one hand, it is reasonable to think that farmers have reference points for the valuation of outcomes, and behave differently if outcomes are greater than the reference point (gains) or smaller (losses). Some examples of reference outcomes are target prices on the futures markets (the target price usually being based on production costs) (Kim et al., 2010), subsistence incomes and solvency thresholds in the context of production choices (e.g., Mahul, 2000), and pollution thresholds (Qiu et al., 2001). Hence, the use of sign-dependent models which frame outcomes as gains and losses could be well adapted to the analysis of farmers' decision making in many contexts.[3] Collins et al. (1991) provided some empirical evidence of reference dependence by investigating the relationship between preference reversals and changes in income with data from grass seed growers. After an income loss, the growers changed their behaviour from risk aversion to risk seeking. On the other hand, climate models forecast higher growing-season temperatures with greater damage to agricultural production and more significant impacts on farm income (Battisti and Naylor, 2009). In addition, the liberalisation of agricultural markets tends to increase price volatility. In this context, it might be interesting to better understand how farmers behave towards unlikely events with dramatic consequences. Probability weighting allows the overweighting of extreme events and low probabilities, and thus could be more and more relevant to model farmers' behaviour. For example, Eales et al. (1990) provided empirical evidence of farmers' tendency to overestimate the mean and underestimate the variance of grain prices, which is compatible with probability weighting. Indeed, Chavas et al. (2010) have called

2. It is fair to say that in earlier tests no theory was identified as a clear-cut winner and that data used to support one theory or the other depend on the problem considered and the individuals' characteristics included into the model (Starmer, 1992; Harless, 1992; Hey and Orme, 1994). The stochastic specification of the choice model has also important consequences on the adequacy between the decision theory tested and the data (Loomes and Sugden, 1998).

3. Safety first models are an earlier and popular attempt of emphasising the role of crisis situations (hunger, bankruptcy) in farmers' decision making (Kataoka, 1963; Roy, 1952; Moscardi and de Janvry, 1977).

for a greater use of behavioural economics to better understand patterns in farmers' decision making.

Among the competing behavioural models, prospect theory (Kahneman and Tversky, 1979; Tversky and Kahneman, 1992) is now viewed as the most convincing alternative to EUT (Camerer, 1998; Starmer, 2000). Indeed, it features the two aforementioned key factors explaining EUT anomalies, namely reference dependence and probability weighting. According to EUT, individuals do not behave differently when faced with gains or losses. They are also supposed to value prospects linearly in respect to objective probabilities. However, they do have subjective perceptions of both probabilities and outcomes, but they are accounted for by the curvature of the utility function. Under PT, individuals have more elaborate preferences, which feature reference dependence and probability weighting. On the one hand, outcomes are considered as either gains or losses, in relation to a labile reference point, and individuals behave differently in terms of one or the other. On the other hand, preferences are non linear in probabilities, which accounts for the fact that individuals distort probabilities into decision weights. Therefore, in PT, risk behaviour is represented as the interplay of utility curvature, probability weighting, and reference dependence. Assuming prospect theory instead of EUT could lead to a very different understanding of farmers' decisions (Tuthill and Frechette, 2004; Mattos et al., 2008; Laciana et al., 2006).

In our paper, we propose to elicit the risk preferences of French farmers in a field-experiment setting under EUT and PT in its cumulative form (CPT). We elicit those preferences from a sample of French farmers using Tanaka et al.'s (2010) experimental design. We extend their work by implementing an econometric approach, estimating a structural model of preferences instead of calculating parameters analytically.[4] This approach is more accurate for multi-parameter models such as PT models because all the parameters are jointly estimated. Moreover, we investigated how parameters correlate with several farmer and farm characteristics.

Our results contribute to a better understanding of risk in the agricultural context in two ways. First, rather than relying on laboratory responses, we provide experimental field evidence favouring the use of CPT over EUT, in some cases. Second, we provide agricultural

4. Following (Harrison and Rutström, 2008, ,p.69), in this paper, a structural model refers to a global model of decision where the 'core' preference parameters are to be estimated. This denomination is used in contrast with the more common approach of estimating (linear) reduced-form equations for each parameter of interest. However, in this paper, the term 'structural' does not give any information about the way error terms are specified.

economists with measures of farmers' preferences under CPT, in relation with farmer and farm characteristics. Specifically, we are not aware of any earlier attempt to elicit such preferences in the context of a developed country.[5] Evidence in favour of preferences departing from the standard EUT should help farm modelling and the designing of adequate policy instruments.

The remainder of this paper is organised as follows. In Section 3.2, we describe the most popular alternatives to EUT for decision making under risk. Then, we survey the experimental studies that have formally (i.e., with a structural model) tested these theories against EUT. In Section 3.3, we describe our experimental protocol. In Section 3.4, the procedures for the estimation of preference parameters under EUT and PT are laid out. Results are presented in Section 4.6. Lastly, we review some of the implications of PT in the field of agricultural economics.

3.2 Relevant Literature

3.2.1 Alternative theories of decision making under uncertainty

Numerous theories have been proposed as alternatives to EUT (see Starmer, 2000, for a complete review). In this section we present those labelled decision-weighting theories, which prove to be the most convincing ones. These theories accommodate probability weighting as well as reference dependence for some of them. We focus on the way decision-weighting theories relate to each other, both historically and technically.

The study of decision-making behaviour under risk has been dominated by EUT since the work of von Neumann and Morgenstern (1947). Although empirical data quickly demonstrated the existence of systematic violations (Allais (1953) paradox for instance), its rigourous axiomatic basis, simplicity of use, and normative appeal have led researchers to adopt it over alternative propositions for decades. Originally defined for risk situations where the space of possible events and corresponding probabilities were objectively known by the decision maker, it was extended by Savage (1954) to subjective probabilities expressing decision makers' beliefs over unknown probabilities. However, this subjective expected utility theory has been criticised for its lack of

5. Pennings and Smidts (2003) investigate reference dependence on a sample of Dutch hog farmers but using non parametrical methods. Reynaud and Couture (2010) elicit risk preferences from French farmers but restrict them to EUT.

generality (Ellsberg (1961) paradox).

A new corpus of decision theories emerged at the beginning of the 80s, notably thanks to insights from psychological experimental research. Today, decision-weighting theories constitute the main alternative to EUT. They hold in common preferences over prospects that are non linear in probabilities, subjects converting objective probabilities of individual outcomes into weights before they make choices. These weights involve a probability weighting function. Among the class of decision-weighting theories, two well-known sub-classes are of particular interest: sign-dependent theories (e.g., Kahneman and Tversky's (1979) separable prospect theory) and rank-dependent theories (e.g., Quiggin's (1982) rank-dependent expected utility theory).

Separable prospect theory (SPT) [6] features a probability weighting function which directly converts individual probabilities into weights, low probabilities being overweighted and high probabilities underweighted. However, SPT has the drawback of violating first-order stochastic dominance. Thus, the main contribution of SPT to the understanding of decision making lies in its framing of outcomes relative to a labile reference point, upper values representing gains and lower values representing losses. Kahneman and Tversky specify a utility function over outcomes, the curve for gains being reflected for losses (reflection effect). In other words, if utility is concave for gains, it is convex for losses. This S-shape stands for a diminishing sensitivity to changes away from the reference point, already well established by EUT in the gain domain. However, the most remarkable characteristic of prospective utility is to exhibit a different slope according to the outcome domain. If it is steeper in the loss domain than in the gain domain, it means that the disutility of a loss is stronger that the utility of a similar gain. This is the concept of loss aversion. Similarly, the reflection effect and the difference of slope applies to the probability weighting function, enhancing the contrast between behaviour towards losses and towards gains.

Some years later, to satisfy stochastic dominance, Quiggin (1982) developed the idea of weights involving cumulative probabilities. In his rank-dependent expected utility theory (RDEUT), the probability weighting function transforms cumulative probabilities rather than individual probabilities, according to the rank of the outcomes. Then, the transformed probabilities are

6. Kahneman and Tversky's (1979) separable prospect theory is sometimes referred to as original prospect theory, in contrast to a later version by Tversky and Kahneman (1992).

combined into decision weights. Thus, the weight attached to an outcome depends on its individual probability, as in SPT, but it also depends on the ranking of that outcome relative to the other outcomes of the prospect. In other words, unlike the preferences under SPT, those under CPT are not separable according to outcomes. The consequence in terms of decision making is that extreme outcomes (along with extreme probabilities) are particularly impacted by decision weights. More precisely, a probability weighting function exhibiting an 'inverse S-shape' represents the overweighting of high-ranked and low-ranked outcomes (especially if they have a low-probability of occurrence) and the underweighting of middle-ranked outcomes (especially if they have a high-probability of occurrence). This pattern is reflected in the loss domain.[7] Tversky and Kahneman's (1992) cumulative prospect theory (CPT) combines the most interesting features of SPT and RDEUT, namely outcome valuation relative to a reference point and cumulative decision weights. In this paper, we elicit the risk preferences of French farmers in a field-experiment setting under CPT as an alternative to EUT.

3.2.2 Experimental elicitation of farmers' risk preferences under non-expected utility theories

Unlike investigations based on EUT (e.g., the seminal papers by Binswanger (1980, 1981)), few researchers have sought to elicit risk preferences of farmers in a field-experiment setting based upon non-expected utility theories. However, some researchers have recently attempted to do so in an effort to better understand the decision-making patterns of rural people in developing countries.

Tanaka et al. (2010) developed a method to elicit CPT preferences and applied it to a sample of rural Vietnamese households. They pointed out that CPT described their data better than EUT, with evidence in favour of utility concavity, loss aversion and an inverse S-shaped probability weighting function. Using the same experimental design, Liu (2010) obtained a similar behaviour pattern for Chinese cotton farmers. Nguyen and Leung (2009) used the same design and sample than Tanaka et al. (2010) but focused on behaviour according to occupation. Farmers, who represented 46% of their sample, were found to be significantly less averse to loss

7. Yaari's (1987) dual theory incorporates the same type of rank-dependent decision weights but assumes risk neutrality. Its pedagogical virtues lies in its intermediary position between expected value models and rank-dependent expected utility models.

than non-farmers.

Following Harrison and Rutström's (2009), Harrison et al. (2010) and Galarza (2009) estimated mixture models of decision. Instead of estimating the parameters of each model assuming only one describes behaviour, in mixture models the coexistence of several theories is explicitly recognizee. Preference parameters are estimated jointly with mixing probabilities which quantify the prevalence of each theory in the sample. Harrison et al. (2010) considered separable prospect theory and EUT in the gain domain only. They relied on a large sample of people from rural Ethiopia, India and Uganda. Whatever the parametric assumptions behind the probability weighting function, they reported a significant underweighting of probabilities over a wide range of probabilities, giving the function either a S or a convex shape. However, when allowing separable prospect theory and EUT to explain the data at the same time, they found significant mixing proportions close to 0.5.

Galarza's (2009) focused on EUT and RDEUT. The author analysed the responses of small-scale cotton producers from Peru. He estimated single models and a two-component mixture model, the latter operating a classification of individuals rather than of observations. Like Harrison et al. (2010), Galarza showed that subjects distorted probabilities, but that mixing proportions were significant as well. About 30% of the cotton producers were estimated to exhibit expected utility while 70% behaved according to RDEUT.

In the context of developed countries, we are not aware of any experimental paper estimating the parameters of some decision-weighting model on a sample of farmers. However, Pennings and Smidts (2003) investigated non parametrically sign-dependency behaviour on Dutch hog farmers. After measuring each respondent's utility, they found evidence for mixed preferences, in relation to farmers' strategy and organisation. Farmers who bought piglets exhibited mostly a S-shaped utility function (55%) (i.e., concave for gains and convex for losses), whereas farmers who bred their own piglets mostly exhibited a fully concave or convex utility function (89%).

3.3 Experimental protocol

3.3.1 Experimental design and procedure

Our experimental design is adapted from the risk task of Tanaka et al. (2010).[8] It consists of three series of choices, which are variants of Holt and Laury's (2002) multiple price lists, see Table 3.1. In practical terms, subjects are presented with a succession of pairs of binary lotteries, each pair being composed of a *safe* lottery (option A) and a *risky* lottery (option B). They are asked to pick one lottery in each row. In the first row, the expected value of lottery A is higher than the expected value of lottery B. As one proceeds down the rows, the expected value of lottery B increases quicker than the expected value of lottery A, and in the last row the expected value of lottery B is higher than the expected value of lottery A. In the first two series, payoffs are all positive whereas, in the third and last series, lotteries mix positive and negative outcomes. To enforce monotonicity, subjects are asked to pick the row in which they prefer lottery B rather than lottery A. Subjects who are very risk averse may never switch — and always choose lottery A — and subjects who are very risk seeking may choose the risky lottery as of the first row — and always choose lottery B. Risk neutral subjects would switch when lottery B overtakes lottery A in terms of expected value.

The 33 lottery choices each subject is presented with are displayed in Table 3.1.[9] We used substantial money amounts from 10 euros to 6,000 euros in absolute value, the mean expected payoff being closed to 205 euros. This high payoff range has two advantages. On the one hand, farmers were presented with money values in euros that they were used to handling in their production choices.[10] On the other hand, we enhanced our chance to detect utility curvature: individuals exhibit a quasi-linear utility at low stakes (Rabin, 2000; Holt and Laury, 2002).

The experiment was carried out from February to June 2010. It took place after a 2-hour face-to-face interview aimed at collecting farmer and farm data and understanding the relation between the adoption of agricultural innovations, production practices and risk management. The experiment lasted around half an hour and was divided into three different tasks: a risk

8. Tanaka et al.'s (2010) experiment is made up of a risk task aiming at measuring CPT parameters and a time task aiming at measuring time preference parameters. However, the two tasks are unrelated and can be implemented independently.

9. The difference in expected payoff between lotteries is not shown to respondents. The effect of providing expected value information is not well documented (Harrison and Rutström, 2008).

10. For instance, the net margin of a traditional rape/wheat/barley rotation is around 430 €/ha/yr in a cereal-growing region (Bocquého and Jacquet, 2010).

task, an ambiguity task, and a time task. In this paper, we only analyse the results from the risk task. A comprehensive introduction of methods and goals, as well as examples, were given to respondents prior to the experiment to ensure a good comprehension of the tasks at hand. Subjects were provided with an initial endowment of 15 euros for their participation. After the subject had completed all three tasks, one row was randomly selected and the lottery chosen by the subject was played for real money.[11] As we were not able to pay the full payoffs (ranging from -600 to 6,000 euros in the risk task), at the beginning of the experiment respondents were advised that they would receive a percentage of the payoffs. However, the exact amount was not announced. The predetermined percentage of 2% was noted on a sheet of paper and enclosed in an opaque envelope prior to visiting respondents.The envelope was laid on the table in front of each respondent at the beginning of the experiment. As such, it is reasonable to think that subjects would still consider the full payoffs when choosing between lotteries.[12] Loss lotteries could be played for real just like gain lotteries, but the initial endowment ensured that final earnings would not be negative. All instructions given to respondents are provided in Appendix C and D.

3.3.2 Sample

We organised an artefactual field experiment[13], using a population of farmers. Most experimental studies elicit risk preferences in a laboratory setting, involving a university student population. The reliance on this student population can be criticised for at least for three reasons. Firstly, there are no grounds for systematically generalising all the results drawn from student responses to other people. Secondly, in the overwhelming majority of cases, there is no rational sampling, which prevents the students participating to the experiment from being representative of an economically significant population. Thirdly, students are more homogeneous relative to the broader population in terms of important socio-demographic characteristics like age and education. Thus, drawing risk preferences from a student sample could fail to reveal any diversity in behaviour. As stressed by Harrison and List (2004), field approaches are complementary to

11. Real money incentives are recommended to ensure respondents' commitment to the experiment and avoid hypothetical bias (Harrison and Rutström, 2008, p.123).

12. This procedure was used by other authors dealing with large payoffs in laboratory (Abdellaoui et al., 2008) or field experiments (Galarza, 2009).

13. According to Harrison and List's (2004) terminology.

Table 3.1: Experimental design

	Option A		Option B		Expected payoff difference (A-B)
Series1					
Row	Prob 30%	Prob 70%	Prob 10%	Prob 90%	
1	400	100	680	50	77
2	400	100	750	50	70
3	400	100	830	50	60
4	400	100	930	50	52
5	400	100	1060	50	39
6	400	100	1250	50	20
7	400	100	1500	50	-5
8	400	100	1850	50	-40
9	400	100	2200	50	-75
10	400	100	3000	50	-155
11	400	100	4000	50	-255
12	400	100	6000	50	-455
Series2					
Row	Prob 90%	Prob 10%	Prob 70%	Prob 30%	
1	400	300	540	50	-3
2	400	300	560	50	-17
3	400	300	580	50	-31
4	400	300	600	50	-45
5	400	300	620	50	-59
6	400	300	650	50	-80
7	400	300	680	50	-101
8	400	300	720	50	-129
9	400	300	770	50	-164
10	400	300	830	50	-206
11	400	300	900	50	-255
12	400	300	1000	50	-325
13	400	300	1100	50	-395
14	400	300	1300	50	-535
Series3					
Row	Prob 50%	Prob 50%	Prob 50%	Prob 50%	
1	250	-40	300	-210	60
2	40	-40	300	-210	-45
3	10	-40	300	-210	-60
4	10	-40	300	-160	-85
5	10	-80	300	-160	-105
6	10	-80	300	-140	-115
7	10	-80	300	-110	-130

Design adapted from Tanaka et al. (2010). Payoffs are in euros.

laboratory approaches to give sharper and more relevant inferences about real behaviour.

We constructed our sample of farmers from 64 rural towns in *Bourgogne*, in the east of France. The region of *Bourgogne* is diversified in terms of agriculture, producing cereal crops, livestock, market vegetables and wine. This diversity enhanced possibilities of detecting heterogeneity in behaviour. We randomly selected 232 subjects from the pool of farmers living in those towns, and first contacted them by mail, followed up by a phone call a few days later to make an appointment.[14] Given the allotted time, 111 farmers accepted to be surveyed. In the end, 107 participated in the experiment, corresponding to a refusal rate of 54% (including farmers who were not reachable, lacked time or did not show up).[15] We believe that the induced selection bias is not critical. Indeed, when they were contacted, farmers were informed about a 2 1/2-hour survey but they were not informed about the nature of our experiment or the payment mechanism. In addition, we controlled for variables such as wealth, trusting and background risk. As a result, there is little chance that farmers' decision to be surveyed, and thus the probability of being included in our sample, was influenced by their risk preferences or some unmeasured variables influencing risk preferences.

Table 4.3 gives some descriptive statistics of our sample in terms of farmer and farm characteristics hypothesised to have an influence on risk preferences. On average, farmers are about 48 years old and have one child living in their household. One third of the farmers have at least a secondary school level of education. The mean farm size is 169 ha, one third of the land being owned by the farmer. Besides their farming activity, 26% of the households receive some income from another professional activity than farming. In terms of production characteristics, one quarter of the farmers raise livestock. Farms located in the northern part of our study area, i.e., facing less favourable pedo-climatic conditions, represented 24% of our sample. Finally, only 21% of farmers state that they generally trust other people.

14. In our sample, farmers having adopted an innovative crop called miscanthus are over-represented. Some statistical weights are then used in order to make the final farmer sample representative of the initial pool of farmers.

15. Galarza (2009) reported a similar refusal rate for his experiment with Peruvian farmers (53% of the farmers contacted did not show up to the experimental sessions or did not stay until the end). Harrison (2007) estimated a refusal rate of 60% in their risk experiment about the Danish population.

Table 3.2: Descriptive statistics of covariates

	Description	Mean value	Std. Dev.
Age	age of the subject (years)	47.68	8.85
NbChildren	number of children in the household	1.11	1.15
EducSup	dummy if education level beyond secondary school	0.32	0.47
Trust	dummy if self-reported as trusting other people	0.21	0.41
FarmSize	total arable area (100 ha)	1.69	0.96
LandOwned	proportion of land out of the arable area which is owned	0.32	0.21
ExtraInc	proportion of the household income coming from another profession than farming	0.26	0.25
DeffPayment	dummy if uses deferred payments	0.23	0.42
Livestock	dummy if has livestock	0.24	0.43
IdleLand	proportion of idle land out of the arable area in 2009	0.03	0.03
IndivOwner	dummy if the farm is a sole proprietorship or a society with only one associate	0.59	0.49
NoSuccessor	dummy if has no successor despite looking for one	0.26	0.44
North	dummy if farm located in the northern part of the study area	0.24	0.43
WheatRisk	importance of risk faced on soft wheat (1-5 score)	3.29	0.55
Nb. of obs.		102	

Variable *WheatRisk* is the mean of several Likert-type items measuring farmers' perception of wheat production exposure to several types of risks (1=not important at all, 5=very important): climate risk, management risk, location risk, price risk, cost risk.

3.4 Estimation methods

3.4.1 Structural estimation

A flexible way of eliciting preference parameters from experimental data is the estimation of some structural models, as initially proposed by Harless and Camerer (1994). In particular, this approach is suitable for specifications with several preference parameters. We follow such a strategy to estimate several models of preferences under EUT and CPT.

Expected utility (EUT) Let us first assume that the utility of income follows the usual power specification defined by (Tversky and Kahneman, 1992; Wakker, 2008):

$$u(y) = \begin{cases} y^r \\ -(-y)^r \end{cases} \tag{3.1}$$

where r is an anti-index of risk aversion, and $(1-r)$ is the Arrow-Pratt coefficient of constant relative risk aversion (CRRA). In the gain domain ($y \geq 0$), this specification implies risk seeking (utility convexity) for $r > 1$, risk neutrality (utility linearity) for $r = 1$, and risk aversion (utility concavity) for $r < 1$. Because $u(.)$ is symmetric with respect to 0, the interpretation of r for gains is reflected for losses, i.e., $r > 1$ stands for risk aversion (utility concavity).

In the experiment, subjects are asked to choose between lottery A $(x_{A,1}, p_A; x_{A,2})$ and lottery B $(x_{B,1}, p_B; x_{B,2})$ over a series of j questions. Thus, at each question, the expected utility of subject i for each lottery (A or B) is written as follows:

$$EU_i^A(y) = p_A * y_{A,1}^{r_i} + (1 - p_A) * y_{A,2}^{r_i} \tag{3.2a}$$

$$EU_i^B(y) = p_B * y_{B,1}^{r_i} + (1 - p_B) * y_{B,2}^{r_i} \tag{3.2b}$$

where $y_{A,1}, y_{A,2}$ and $y_{B,1}, y_{B,2}$ are the payoffs involved in lottery A and lottery B respectively; and p_A and p_B are the probabilities associated to payoffs on the left in lottery A and B respectively.

Assuming that subjects follow a utility-maximising behaviour, observed choices are driven by a latent choice index Δ which is the difference between utilities of lotteries A and B (Harrison and Rutström, 2008):

$$\Delta_i^{EUT} = EU_i^A - EU_i^B \tag{3.3}$$

Then, we build upon the random utility model (Manski and Lerman, 1977) to develop an empirical model of choice. Utility is decomposed into a deterministic part which contains the parameters to be estimated (r) and depends on observable individual characteristics X , plus a random part capturing unobserved heterogeneity in utility. The relationship between r and the vector X is supposed to be linear and constant over subjects:

$$r_i = \theta X_i \tag{3.4}$$

where θ is a vector of parameters to be estimated.

Thus, subjects' choices between lottery A and lottery B δ_i can be described by the following binary choice model:

$$\delta_i^* = \Delta_i^{EUT}(X_i) + \varepsilon_i, \qquad \delta_i = \begin{cases} A & \text{if } \delta_i^* > 0 \\ B & \text{otherwise} \end{cases} \tag{3.5}$$

where ε is a normally distributed error term with mean zero and known variance v.

We can derive from the above equations the probability that subject i choose lottery A:

$$\begin{aligned} Pr(\text{choose lottery A } |X_i) &= Pr(\Delta_i^{EUT} + \varepsilon_i > 0|X_i) \\ &= 1 - Pr(\varepsilon_i \leq -\Delta_i^{EUT}|X_i) \\ &= 1 - \Phi(-\Delta_i^{EUT}(X_i)) \\ &= \Phi(\Delta_i^{EUT}(X_i)) \end{aligned} \tag{3.6}$$

where $\Phi(.)$ denotes the standard normal distribution function. The right-hand side lies in the interval $[0;1]$ for any values of Δ_i^{EUT}.

We estimate the preference parameter r with maximum likelihood methods. The likelihood of the observed choices, conditional on the EUT and CRRA specifications being true, is as follows:

$$\ln L^{EUT}(\delta, X; r) = \sum_k \Big[\ln \Phi(\Delta_k^{EUT}) \times \mathbb{1}(\delta_k = A) + \ln[1 - \Phi(\Delta_k^{EUT})] \times \mathbb{1}(\delta_k = B) \Big] \tag{3.7}$$

where k indexes the different choices pooled over subjects ($k = (i,j)$), $\mathbb{1}$ is the indicator function, $\delta_i = A[B]$ denotes the choice of lottery A [B]; and X is a vector of observable characteristics of the subjects. The maximum-likelihood estimation for the r parameter is therefore:

$$\hat{r} = \arg\max \ln L^{EUT}(\delta, X; r). \tag{3.8}$$

Since the CRRA might appear very restrictive, one may consider other functional forms of utility which allow, for instance, for varying degrees of relative risk aversion. Here we consider a variant of Saha's (1993) Expo-Power (EP) utility function (Holt and Laury, 2002; Abdellaoui et al., 2007) :

$$u(y) = \begin{cases} [1 - \exp(-\beta y^{\alpha})]/\beta, & (\alpha \neq 0, \beta \neq 0, \alpha.\beta > 0) \quad \text{if } y \geq 0 \\ [1 - \exp(\beta(-y)^{\alpha})]/\beta, & (\alpha \neq 0, \beta \neq 0, \alpha.\beta > 0) \quad \text{if } y < 0 \end{cases} \tag{3.9}$$

where α and β are two parameters involved in the Arrow-Pratt coefficients of absolute and relative risk aversion. These coefficients are respectively:

$$A(y) = -u''(y)/u'(y) \qquad = [1 - \alpha + \alpha\beta y^{\alpha}]/y \tag{3.10}$$

$$R(y) = -yu''(y)/u'(y) \qquad = 1 - \alpha + \alpha\beta y^{\alpha}. \tag{3.11}$$

The EP specification accommodates the empirical finding of decreasing absolute risk aversion (DARA) and increasing relative risk aversion (IRRA) for $0 < \alpha < 1$ and $\beta > 0$ (Saha, 1993). Provided that $\alpha > 0$, a positive change in either α or β increases the degree of risk aversion (Saha, 1993). [16] The EP utility function collapses with a constant absolute risk aversion (CARA) specification of parameter β when $\alpha = 1$ and tends to the previous CRRA specification of parameter α when β tends to 0.

Replacing the CRRA utility by the EP utility in Equations (3.2a) and (3.2b) leads to a likelihood function similar to the one defined in Equation (3.7). The maximum likelihood joint estimation for α and β is therefore :

$$(\hat{\alpha}, \hat{\beta}) = \arg\max \ln L^{EUT}(\delta, X; \alpha, \beta). \tag{3.12}$$

Cumulative Prospect Theory (CPT) An alternative paradigm for subject behaviour could be cumulative prospect theory (CPT). Following Tversky and Kahneman (1992), a power utility function defined separately over gains and losses is assumed:

$$u(y) = \begin{cases} y^{\sigma} & \text{if } y > 0 \\ 0 & \text{if } y = 0 \\ -\lambda(-y)^{\sigma} & \text{if } y < 0, \end{cases} \cdot \tag{3.13}$$

16. With the exception of very small values of y in the case of α.

where σ is an anti-index of utility concavity [17] and λ is the coefficient of loss aversion of the decision maker. [18] This specification implies a higher (resp. lower) sensitivity to loss than to gain for $\lambda > 1$ (resp. $0 < \lambda < 1$). The usual empirical finding is $\lambda > 1$ along with $\sigma < 1$ (concave utility).

Following Tversky and Kahneman (1992), decision weights defined over the cumulative probability distributions are introduced. The value of the prospect $(y_1, p; y_2)$ is as follows:

$$U(y_1, p; y_2) = \begin{cases} \omega(p).u(y_1) + [1 - \omega(p)].u(y_2) & \text{if } y_1 \geq y_2 \geq 0 \text{ or } y_1 \leq y_2 \leq 0 \\ \omega(p).u(y_1) + \omega(1-p).u(y_2) & \text{if } y_1 < 0 < y_2. \end{cases} \tag{3.14}$$

where $\omega(.)$ is a probability weighting function. [19] It is strictly increasing from the unit interval into itself and satisfies $\omega(0) = 0$ and $\omega(1) = 1$.

The form of the weighting function has been widely discussed. Following Tanaka et al. (2010), Prelec's (1998) specification is preferred:

$$\omega(p) = \exp\left[-(-\ln p)^{\gamma}\right] \tag{3.15}$$

where γ is the parameter controlling the curvature of the probability weighting function.

This parameter can be interpreted as an index of likelihood sensitivity, $\gamma = 1$ reflecting the absence of probability distortion ($\omega(p) = p$) [20]. In other words, as γ decreases, the distinction between different levels of likelihood gets more and more blurred, and they tend to be perceived as all being equal. The normal assumption, backed by a substantial amount of empirical

17. In the original specification of CPT by Tversky and Kahneman (1992), two distinct parameters represent the utility function curvature, one for the gain domain and the other for the loss domain. However, in most empirical applications they are merged (see (Wakker, 2010, p.267-271) for an explanation of the analytical reasons justifying such a simplification).

18. In PT, risk attitude depends on other factors besides utility, namely loss aversion and probability weighting. Thus, σ is no longer an index of risk attitude but just a measure of utility curvature.

19. Tversky and Kahneman's (1992) CPT allows different probability weighting functions, one for the gain domain and the other for the loss domain. However, in most empirical applications they are the same.

20. Originally, Prelec's (1998) function has two parameters, one standing for likelihood sensitivity, and the other one for pessimism. Indeed, the prevailing empirical finding is that deviation from linear probability weighting results from a combination of both phenomena. Whereas likelihood sensitivity is viewed as a consequence of cognitive limitations in the perception of objective probabilities, pessimism is considered as a motivational distortion of probabilities which depends on outcome ranks. If the decision maker is pessimistic, bad outcomes are overweighted while good outcomes are underweighted. Optimism is defined by the opposite behaviour. In terms of the impact on the shape of the probability weighting function, likelihood sensitivity impacts curvature whereas pessimism impacts elevation (Wakker, 2010). However, the effect of pessimism on probability weighting was found to be low compared to likelihood sensitivity, and as such, is often ignored in empirical applications.

evidence is that $\gamma < 1$. This gives the weighting function an 'inverse S-shape', and characterises an overweighting of low probabilities (and extreme events) and an underweighting of high probabilities. If $\gamma > 1$ the function takes the less conventional 'S-shape', with convexity for smaller probabilities and concavity for larger probabilities. At the extreme, when γ is very high, probabilities tend to be perceived as either 0 or 1. The effect of probability weighting on overall risk aversion depends on the weighting function curvature, and hence on the given probability domain. Probability weighting generates risk aversion if the function is convex (i.e., if the weighting function is inverse S-shaped, for outcomes with high probabilities) but generates risk seeking if the function is concave (i.e., if the weighting function is inverse S-shaped, for outcomes with low probabilities). This CPT model reduces to EUT-CRRA utility (Equation (3.1)) if $\lambda = 1$ and $\gamma = 1$.

The derivation of the likelihood function with CPT specification follows the same steps than with EUT. By denoting Δ^{CPT} the difference in prospective utilities, the likelihood of the observed responses, conditional on our CPT specification is written as follows:

$$\ln L^{PT}(\delta, X; \sigma, \lambda, \gamma) = \sum_k \Big[\ln \Phi(\Delta_k^{CPT}) \times \mathbb{1}(\delta_k = A) + \ln[1 - \Phi(\Delta_k^{CPT})] \times \mathbb{1}(\delta_k = B) \Big] \quad (3.16)$$

and the maximum-likelihood estimation for $(\sigma, \lambda, \gamma)$ is therefore:

$$(\hat{\sigma}, \hat{\lambda}, \hat{\gamma}) = \arg\max \ln L^{PT}(\delta, X; \sigma, \lambda, \gamma). \quad (3.17)$$

The implementation of the maximum likelihood has been done in STATA following the procedure for survey data (*svy:* prefix). In particular, the standard errors on estimates are corrected for the possibility that responses from the same subject are correlated. The STATA program has been adapted from Harrison and Rutström (2008) . It uses the STATA maximum likelihood routines to estimate structural choice models under EUT and CPT.

Table 3.3: Distribution of switching points

Switching point	Proportion of respondents		
	Series 1	Series 2	Series 3
1	15.0	26.2	10.3
2	2.8	1.9	7.5
3	0.9	0.9	14.0
4			13.1
5	2.8	2.8	24.3
6	7.5	1.9	4.7
7	14.0	2.8	3.7
8	1.9	8.4	
9	4.7	4.7	
10	8.4	3.7	
11	1.9	2.8	
12	1.9	6.5	
13			
14		4.7	
never	38.3	32.7	22.4
Total	100.0	100.0	100.0
Number of observations	107	107	107

3.5 Results

3.5.1 First results

The distribution of switching points over the 107 respondents is shown in Table 3.3. For each subject, we calculated the CPT parameters corresponding to the observed choices using the common midpoint technique, adapted by Tanaka et al. (2010) to CPT.[21] Then, we derived estimates of mean values and corresponding standard errors for the underlying population. We found that, on average, σ is 0.51 (with a 95% confidence interval of $[0.41, 0.62]$) and λ is 3.76 (with a 95% confidence interval of $[2.93, 4.58]$). Regarding likelihood sensitivity, we found that γ mean value is 0.65 with a 95% confidence interval of $[0.56, 0.73]$). These estimates are in line with those calculated with similar methods by Tanaka et al. (2010) and Liu (2010) for rural people from developing countries.[22]

21. Bounds for σ and γ are jointly inferred by crossing responses to Series 1 and Series 2, each series providing several possible combinations of intervals for σ and γ. Then, conditionally to the σ value previously elicited, bounds for γ can be inferred from Series 3. Parameter values are approximated by taking the mid-point of intervals. When there is no switch, the values at the boundary are used.

22. Tanaka et al. (2010) and Liu (2010) report respectively mean values of about 0.60 (between 0.59 and 0.63) and 0.52 for utility convexity (σ in this paper) and 2.63 and 3.47 for loss aversion (λ). They find 0.74 and 0.69 for likelihood sensitivity (γ).

3.5.2 Estimation of a structural model of risk preferences

In this section we estimate various decision models, namely two models of expected utility and one model of cumulative prospective utility, as defined in Section 3.4. For each decision model, we consider (i) homogeneous risk preferences between respondents (model 1), (ii) heterogeneous preferences driven by farmer characteristics (model 2), (iii) heterogeneous preferences driven by farm characteristics (model 3) , and (iv) heterogeneous preferences driven jointly by the two previous sets of regressors.

Expected utility theory Table 3.4 reports the maximum likelihood estimates obtained under EUT, assuming a CRRA specification for utility. Model 1 corresponds to estimates assuming homogeneous risk preferences, models 2 and 3 introduce respectively farmer and farm characteristics as covariates, and model 4 assumes heterogeneous risk preferences respective to both sets of covariates. In model 1, the parameter r is estimated to be 0.21, with a 95% confidence interval between 0.17 and 0.25. Figure 3.1 displays the distribution of the predicted values of r, using model 4 which includes the full set of covariates. These results indicate that over the high outcomes considered in the experiment, farmers exhibit a very risk averse and quite homogeneous behaviour. Indeed, the CRRA coefficient $1-r$ is predicted to be over 0.5 for the whole sample, which contrasts with the moderate values obtained with other experimental data from developed countries. As shown in Table 3.4, we could not find any significant covariate for the r parameter when the full set of covariates is included.

Relaxing the CRRA assumption, Table 3.5 gives the estimates from our data assuming that utility follows the more flexible EP form. As for the CRRA specification, model 1 includes no covariates and models 2 to 4 include covariates for each risk parameter. In the first case, $\hat{\alpha}$ is 0.29 and $\hat{\beta}$ is 0.12, with 95% confidence intervals being respectively $[0.25, 0.33]$ and $[0.08, 0.16]$. Since $\hat{\alpha}$ is significantly lower than 1 and $\hat{\beta}$ is significantly higher than 0, risk preferences appear to be characterised by DARA and IRRA over the outcome domain used in the experiment. These results are in line with a common experimental finding involving a student population (Holt and Laury, 2002).[23] From model 4 we observe that several farm and farmer characteristics influence α and β estimates, most often in opposite directions. Thus, the effect of such covariates

23. However, Harrison (2007) reported from a field experiment that there is no evidence to reject CRRA for the Danish population. Moreover, (Harrison and Rutström, 2008, p.77) outlined that IRRA might be an artifact of the specification chosen to allow subjects to make some errors.

Table 3.4: Maximum likelihood estimates of preferences using EUT-CRRA model

	Model 1		Model 2		Model 3		Model 4	
Covariate	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
r Constant	0.212***	(0.020)	0.097	(0.106)	0.029	(0.111)	-0.206	(0.310)
Age			0.002	(0.002)			0.004	(0.003)
NbChildren			0.012	(0.015)			0.003	(0.019)
EducSup			0.088	(0.062)			0.060	(0.053)
Trust			-0.071	(0.137)			0.007	(0.093)
FarmSize			-0.001	(0.018)			0.024	(0.043)
LandOwned			-0.113	(0.109)			-0.119	(0.145)
ExtraInc			0.017	(0.121)			0.021	(0.089)
DeffPayment			0.022	(0.048)			-0.020	(0.042)
Livestock					0.018	(0.034)	0.032	(0.064)
IdleLand					-0.820	(0.571)	-0.514	(0.751)
IndivOwner					0.070	(0.043)	0.101	(0.144)
NoSuccessor					0.029	(0.045)	0.059	(0.057)
North					-0.059	(0.050)	-0.088	(0.082)
WheatRisk					0.046*	(0.027)	0.034	(0.031)
Model p-value	.		0.118		0.099		0.346	
Nb. of obs. /clusters	3531/107		3399/103		3498/106		3366/102	
Specific tests on estimated coefficients (p-values)								
r: Constant=1	0.000							

*, ** and *** stand for significance at the 10, 5 and 1% level respectively. Standard errors allow for our survey data design, including clustering effects.

on subjects' risk aversion is unclear. As a result, we focus on the covariates which influence the two EP parameters in the same direction. As expected, farmers characterised by either a higher education or as trusting exhibit significantly lower risk aversion than either low-educated or non-trusting farmers. We also find that farm size has a negative impact on risk aversion. On the contrary, individual owners tend to be more risk averse than non-individual owners.

Cumulative prospect theory Table 3.6 reports maximum likelihood estimates under CPT specification. Again, model 1 applies to the homogeneous assumption and models 2 to 4 to the heterogeneous assumption. The estimates of the three CPT risk parameters σ , λ and γ are all significantly different from 1 at the 1% level, implying loss behaviour and probability weighting. The estimated mean values for σ is 0.28 (with a 95% confidence interval of $[0.25, 0.31]$), consistent with diminishing outcome sensitivity and concave utility. However, it is slightly higher than the estimate of r under EUT-CRRA, meaning that some of the utility concavity is captured by loss behaviour and probability weighting. Indeed, the loss aversion parameter λ is estimated to be 2.26, with a confidence interval between 1.79 and 2.73. Thus, farmers are about twice as sensitive to losses than to gains. In addition, the likelihood sensitivity parameter γ is estimated to be 0.77, with a 95% confidence interval between 0.65 and 0.89. This provides some evidence

Table 3.5: Maximum likelihood estimates of preferences using EUT-EP model

	Model 1		Model 2		Model 3		Model 4	
Covariate	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
α Constant	0.288***	(0.018)	0.388	(0.268)	0.158	(0.111)	0.078	(0.245)
Age			-0.000	(0.004)			0.005**	(0.003)
NbChildren			0.007	(0.024)			0.058**	(0.023)
EducSup			-0.003	(0.082)			-0.222***	(0.058)
Trust			-0.106	(0.072)			-0.078	(0.063)
FarmSize			-0.010	(0.035)			-0.143***	(0.033)
LandOwned			-0.097	(0.101)			-0.031	(0.132)
ExtraInc			-0.102	(0.095)			-0.280***	(0.084)
DeffPayment			0.045	(0.097)			0.036	(0.041)
Livestock					0.010	(0.044)	0.215***	(0.053)
IdleLand					-0.267	(0.527)	2.663**	(1.205)
IndivOwner					0.053	(0.052)	0.034	(0.062)
NoSuccessor					0.072	(0.046)	-0.055	(0.039)
North					0.026	(0.034)	-0.115	(0.104)
WheatRisk					0.024	(0.026)	0.030	(0.022)
β Constant	0.119***	(0.022)	0.250*	(0.132)	0.311***	(0.112)	0.551***	(0.203)
Age			-0.003	(0.002)			-0.010**	(0.004)
NbChildren			-0.004	(0.012)			-0.027	(0.018)
EducSup			-0.123*	(0.068)			-0.246	(0.155)
Trust			0.093	(0.184)			-0.144**	(0.057)
FarmSize			0.008	(0.029)			-0.000	(0.059)
LandOwned			0.138	(0.168)			0.208**	(0.084)
ExtraInc			-0.028	(0.173)			0.269	(0.167)
DeffPayment			-0.041	(0.044)			-0.007	(0.016)
Livestock					-0.015	(0.042)	-0.005	(0.033)
IdleLand					1.131*	(0.594)	-0.904	(0.876)
IndivOwner					-0.085	(0.090)	0.088***	(0.033)
NoSuccessor					-0.031	(0.041)	0.047	(0.042)
North					0.056*	(0.033)	0.171***	(0.064)
WheatRisk					-0.047*	(0.025)	-0.033	(0.026)
Model p-value	.		0.763		0.160		0.000	
Nb. of obs. /clusters	3531/107		3399/103		3498/106		3366/102	
Specific tests on estimated coefficients (p-values)								
α: Constant=1	0.000							
β: Constant=0	0.000							

*, ** and *** stand for significance at the 10, 5 and 1% level respectively. Standard errors allow for our survey data design, including clustering effects.

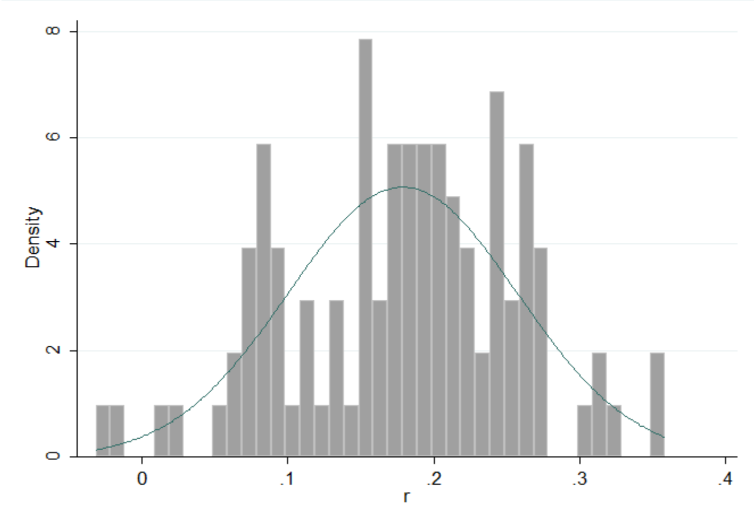


Figure 3.1: Distribution of predicted r values in the case of EUT-CRRA with heterogeneous preferences

of probability distortion in the expected direction: the weighting function is 'inverse S-shaped' which characterises an overweighting of extreme events, along with an overweighting of low probabilities and an underweighting of high probabilities. Our estimates of loss aversion and likelihood sensitivity are very similar to the values (2.25 and 0.61 (for gains, 0.69 for losses)) reported by Tversky and Kahneman (1992) from a student sample.

Figure 3.2 represents the distributions of $\hat{\sigma}$, $\hat{\lambda}$ and $\hat{\gamma}$ obtained under CPT with the full set of covariates (model 4). Estimated utility curvature distribution is similar to the one under EUT-CRRA, that is to say quite homogeneous over subjects who exhibit a strongly concave utility function ($\hat{\sigma} < 0.5$). However, the distribution is shifted towards the right, showing that some of the utility concavity has been transferred to the other risk parameters. Estimated loss aversion and likelihood sensitivity are much more widespread than utility curvature. Indeed, a sizeable proportion of farmers is expected to be extremely loss averse (e.g., $\hat{\lambda}$>5) or, on the contrary, loss seeking ($\hat{\lambda} < 1$). Many farmers also exhibit an extreme likelihood insensitivity ($\hat{\gamma}$ close to 0), and there is some evidence of an underweighting of extreme events for some farmers ($\hat{\gamma} > 1$).[24] In Table 3.6, we observe that confident farmers have a less concave utility than unconfident farmers, which confirms the previous finding under EUT-EP that, overall, trust tends to decrease risk aversion. As for λ variability, it can be explained by the effect of

24. In Figure 3.2, we have represented the distribution of $\hat{\gamma}$ on the interval $[-5, 5]$. We then exclude from the graphic 25 individuals for which the predicted value for the parameter controlling the curvature of the probability weighting function is greater than 10. This set of individuals only perceive probabilities as being either 0 or 1.

age and income stability. The older the farmer and the more stable the household income, the lower the loss aversion. Moreover, farmers having completed higher education are found to be less loss averse than low-educated farmers. Nguyen and Leung (2009) reported a similar effect of education on loss aversion in a Vietnamese context. There is also a positive effect of the proportion of idle land on loss aversion but it is barely significant. As far as likelihood sensitivity is concerned, we find that trusting farmers are more prone to discriminate between probabilities than non-trusting farmers. One explanation may be that they rely more on the objective information they are given.

There does not appear to be major differences in risk behaviour in relation to liquidity constraints, proxied by farmers' use of deferred payments. This results holds whatever the theoretical decision framework considered. This result conflicts with some empirical and theoretical studies (Gollier, 2001; Guiso and Paiella, 2008) that demonstrate the positive impact of liquidity constraints on risk aversion due to a shortening of decision-makers' time horizon and a reduction of consumption-smoothing ability.

Moreover, we cannot see find any significant effect of farm risk on risk behaviour, farm risk being proxied by farmers' valuation of the riskiness of their own wheat production. This result contrasts with the theoretical predictions of Gollier and Pratt (1996) and Quiggin (2003) about the influence of background risk on decision making. Though, even when inducing an explicit background risk in a laboratory setting, Lusk and Coble (2008) found that the effect of background risk on risk preferences was not particularly large either. The authors presented three possible explanations: the existence of non-controlled background risk, the prevalence of non-expected utility behaviour among subjects and the tendency to assess independent risks in isolation rather than jointly. These explanations apply in our case. First, non-controlled background risk can arise from other farm activities. In addition, although we were cautious about accounting for wheat risks that could not be covered in the short-term, when making lottery choices farmers might have assessed a residual farm risk, once coverage mechanisms had functioned. Second, as shown by Quiggin (2003), in the case of rank-dependent preferences, independent risks are complementary, that is aversion to one risk is reduced by the presence of an independent background risk. Gollier and Pratt (1996) proved the opposite for expected utility preferences. Thus, if preference functionals are actually mixed among subjects and situations

(Harrison and Rutström, 2009), our aggregate results would not be able to discriminate between the two opposing phenomena. Third, it seems reasonable to think that farmers easily disregard farm risk when assessing foreground risk if foreground risk consists in stylised lottery choices. Further research could assess to what extent framing impacts the effect of background risk on preferences.

3.6 Implications for agricultural economists

Within the framework of PT, utility curvature, probability weighting and loss aversion all affect the way individuals evaluate risky outcomes, which in turn modifies their behaviour. Thus, reasoning farmers' risk preferences assuming PT rather than EUT may help better explain farmers' decision making. Indeed, there are studies that provide arguments for why assuming PT instead of EUT may matter if we are to deliver more accurate modelling and predictions. We review some of them in this section, distinguishing the consequences of loss aversion from the consequences of probability weighting.

3.6.1 Reference dependence and loss aversion

In our field-experiment setting, we have found that farmers are roughly twice as sensitive to loss as to corresponding gains, gains and losses being defined in relation to a reference point. Reference dependence means that people care about changes in their wealth (deviations from the reference point) rather than their absolute wealth level (initial or final wealth) as in EUT (Kahneman and Tversky, 1979; Wakker, 2010). Thus, the reference point has potentially important consequences on people's behaviour. However, it is highly variable, depending on context and framing. In a recent study, Liu and Huang (2011) found that loss aversion could explain in a significant way pesticide use by Chinese cotton farmers, farmers being more loss averse spraying smaller amounts of pesticides because of health concerns. However, even if such a direct relationship cannot be tested in all cases, the agricultural literature provides several examples where reference dependence and loss aversion can explain deviations from EUT. We distinguish between two empirical phenomena, that is to say the gain-loss framing and the endowment effect.

The most obvious empirical phenomena regarding loss aversion is the difference in framing a

Table 3.6: Maximum likelihood estimates of preferences using CPT model

		Model 1		Model 2		Model 3		Model 4	
	Covariate	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
σ	Constant	0.280***	(0.013)	0.232**	(0.097)	0.133	(0.169)	0.014	(0.211)
	Age			0.001	(0.002)			0.003	(0.003)
	NbChildren			-0.000	(0.012)			-0.008	(0.031)
	EducSup			0.041	(0.043)			0.056	(0.062)
	Trust			-0.116***	(0.042)			-0.085**	(0.042)
	FarmSize			0.006	(0.013)			0.002	(0.021)
	LandOwned			-0.019	(0.085)			-0.044	(0.111)
	ExtraInc			0.058	(0.072)			0.069	(0.084)
	DeffPayment			0.015	(0.034)			-0.003	(0.026)
	Livestock					0.002	(0.059)	0.021	(0.044)
	IdleLand					-0.382	(1.992)	0.103	(0.452)
	IndivOwner					0.012	(0.043)	0.033	(0.041)
	NoSuccessor					0.039	(0.034)	0.024	(0.063)
	North					-0.022	(0.029)	-0.051	(0.037)
	WheatRisk					0.043	(0.033)	0.026	(0.039)
λ	Constant	2.275***	(0.241)	6.620***	(1.918)	3.956***	(1.494)	10.708***	(3.728)
	Age			-0.061*	(0.033)			-0.085**	(0.041)
	NbChildren			-0.060	(0.196)			0.385	(0.334)
	EducSup			-2.073***	(0.544)			-2.719**	(1.268)
	Trust			0.211	(0.473)			-0.131	(0.721)
	FarmSize			-0.017	(0.209)			0.116	(0.419)
	LandOwned			0.179	(1.099)			1.131	(1.479)
	ExtraInc			-2.199*	(1.121)			-3.112***	(1.117)
	DeffPayment			0.641	(0.487)			0.707	(0.732)
	Livestock					0.210	(0.796)	-1.003	(0.645)
	IdleLand					21.662	(24.960)	21.116*	(12.692)
	IndivOwner					-0.544	(0.543)	-0.664	(0.607)
	NoSuccessor					0.006	(0.701)	-1.168	(1.332)
	North					1.183*	(0.610)	1.062	(0.869)
	WheatRisk					-0.618	(0.384)	-0.937	(0.653)
γ	Constant	0.655***	(0.077)	0.286	(0.564)	0.399	(0.846)	-0.329	(1.897)
	Age			0.010	(0.012)			0.028	(0.027)
	NbChildren			0.013	(0.059)			-0.036	(0.062)
	EducSup			0.262	(0.186)			0.372	(0.336)
	Trust			22.202***	(5.237)			29.153***	(6.638)
	FarmSize			-0.003	(0.052)			-0.060	(0.121)
	LandOwned			-0.516	(0.390)			-0.868	(0.810)
	ExtraInc			-0.356	(0.321)			-0.284	(0.223)
	DeffPayment			-0.068	(0.152)			-0.136	(0.149)
	Livestock					0.169	(0.232)	0.297	(0.267)
	IdleLand					-1.871	(7.776)	-2.924	(4.745)
	IndivOwner					0.277*	(0.154)	-0.044	(0.434)
	NoSuccessor					0.039	(0.216)	0.161	(0.207)
	North					-0.173	(0.198)	-0.259	(0.525)
	WheatRisk					0.029	(0.200)	-0.009	(0.185)
Model p-value		.		0.002		0.507		0.000	
Nb. of obs. /clusters		3531/107		3399/103		3498/106		3366/102	
Specific tests on estimated coefficients (p-values)									
σ: Constant=1		0.000							
λ: Constant=1		0.000							
γ: Constant=1		0.000							

*, ** and *** stand for significance at the 10, 5 and 1% level respectively. Standard errors allow for our survey data design, including clustering effects.

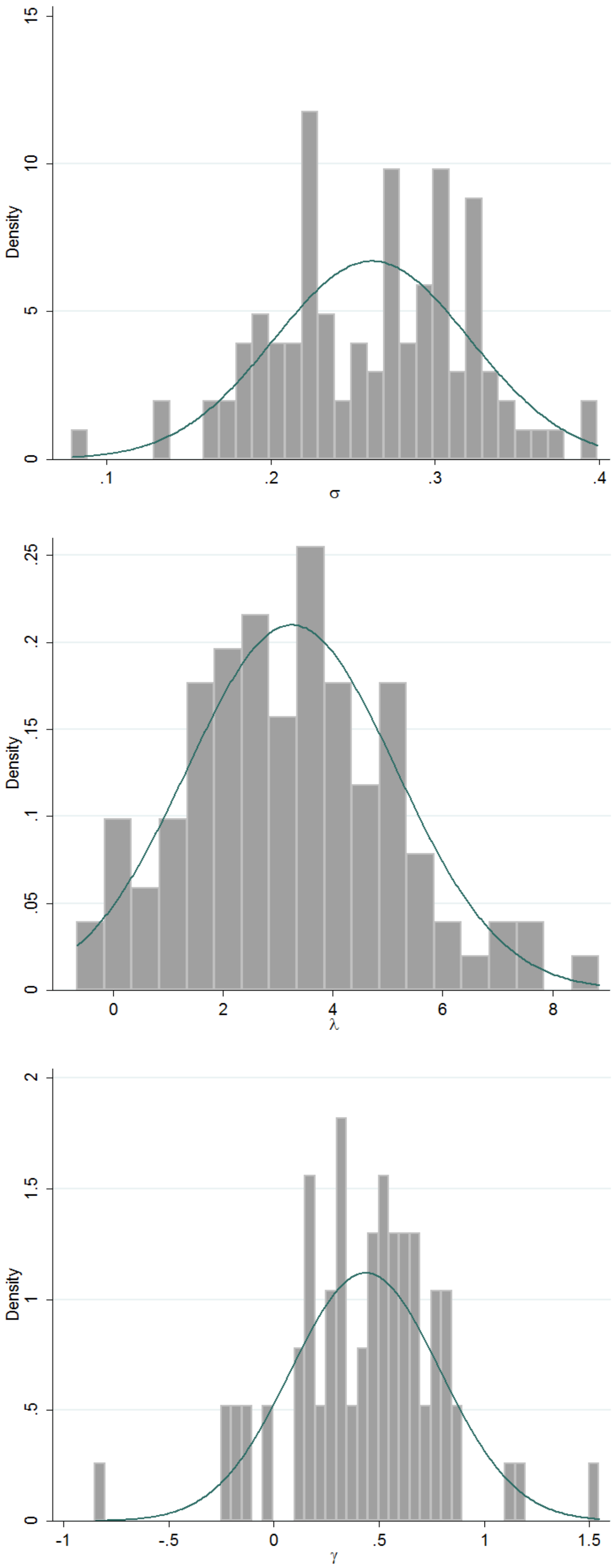


Figure 3.2: Distribution of predicted risk parameters in the case of CPT with heterogeneous preferences

good, a service or a monetary unit as a gain or a loss. For instance, in crop contracts, the base price can be considered as a reference point, and performance incentives (e.g., quality rewards) produce deviations from this point. Two frames are possible: a high base price, along with penalties for poor performance, or a relatively low base price combined with rewards for good performance (Just and Wu, 2005). The gain-loss disparity implies that penalties and rewards are not perfect substitutes as in EUT, penalties being overweighted relative to rewards. Thus, a contract involving penalties should provide the farmer with a higher base price than a contract involving commensurate rewards in order to keep the participation rate stable. Hence, as a rule, one could recommend favouring the reward system which is less costly to the principal. However, other context effects may alter this statement. Indeed, Just and Wu (2005) have shown analytically that the optimal contract design further depends on if the producer evaluates the options outside the contract.

The same gain-loss framing effect influences the design of public incentives as penalties or bonuses. Contrary to the contract case, a general recommendation would be to prefer a penalty system to induce desired behaviour, besides budget considerations. Huijps et al. (2010) provided empirical evidence that farmers are more sensitive to penalties rather than bonuses regarding the adoption of milking practices aimed at improving cattle health in dairy farms.

A second empirical manifestation of loss aversion is the endowment effect [25], corresponding to the fact that people demand more to give up an object (good or service) (willingness-to-accept (WTA)) than they would accept to pay to acquire it (willingness-to-pay (WTP)) (Thaler, 1980; Kahneman et al., 1991). In other words, the disutility of giving up an object is greater than the utility of acquiring it. One of the most documented applications of the endowment effect is the explanation of the WTA-WTP gap in the valuation of objects by consumers (Sayman and Öncüler, 2005; Hjorth and Fosgerau, 2011). There is no reason why the endowment effect would not be present in the increasingly popular studies eliciting farmers' willingness to comply with agri-environmental schemes, for instance by reducing pesticide use (Christensen et al., 2011), growing nitrogen fixing crops (Espinosa-Goded et al., 2010), or providing ecosystem services (Wossink and Swinton, 2007). More generally, any study measuring the sensitivity of farmers' adoption of an item to a change in the attractiveness of that item [26] is potentially subject to

25. The endowment effect is a specific form of the statu quo bias (Samuelson and Zeckhauser, 1988).

26. Examples of items include agri-environmental contracts, but also best management practices or new technologies (e.g., irrigation water, innovative crops). The attractiveness (utility) of an item can be influenced

the endowment effect if the sample includes both farmers who *had* and *had not* adopted the item at the time of the study. Huijps et al. (2010) provides empirical evidence in the case of some milking practices aiming to reduce mastitis in dairy cattle. Farmers who had already implemented the given measure were asked if they would abandon the measure in response to different levels of decreases in costs and efficiency. The other farmers were asked if they would implement the measure in response to increases in costs and efficiency of the same magnitude. The authors found that, on average, farmers who had already implemented the given measure were less willing to change their behaviour than the other farmers who were willing to in response to a symmetric stimulus. In that experiment, transaction costs were not high enough to explain their reluctance to change behaviour.

3.6.2 Probability weighting

Our results shed light on the fact that farmers distort outcome probabilities into cumulative decision weights, the extent of the distortion depending on both the rank and the likelihood of the given outcome. Indeed, farmers tend to give more weight to extreme-ranked outcomes, particularly the exceptional ones. In terms of overall risk attitude, probability weighting implies risk seeking for small-probability, high-ranked gains as well as for moderate- and high-probability, low-ranked losses (whereas expected utility implies risk seeking for losses only).

Insurance demand is one prominent example where probability weighting can explain deviations from the behaviour predicted by EUT. If individuals are risk averse whatever the outcome domain as postulated by EUT, it is in their best interest to purchase insurance because they are willing to pay a small guaranteed amount (the insurance premium)[27] in order to avoid a potential but much larger loss.[28] However, voluntary insurance is not what is always observed in the field, including in the agricultural sector. Participation by farmers in multiperil crop insurance has historically been low in a number of countries, until substantial premium subsidies or compulsory measures were implemented by public authorities, notably in the U.S. (Glauber,

by one trait (e.g., cost, efficacy, image) or several traits at the same time, the latter being typical of choice experiments.

27. At a maximum, the insurance premium should equal the decision-maker's risk premium, which depends on the decision-maker's degree of risk aversion. Otherwise, the decision's maker would refuse the insurance.

28. If the insurance scheme is actuarially fair, i.e. the insurance premium equals (or is higher than) the expected loss, EUT predicts that the decision-maker purchases full insurance, whatever the decision-maker's aversion to risk. If the scheme is actuarially unfair, the decision-maker insures only part of the loss, depending on the difference between the premium and the expected loss, as well as the decision-maker's degree of risk aversion.

2004; Enjolras and Sentis, 2011). Several explanations for this have been provided. On the insurers' side of the issue, there is asymmetries of information (adverse selection and moral hazard problems) or high administrative costs. On the farmers' side of the issue, there is for example the competition between insurance and other hedging strategies at the farm level. The weighting of objective probabilities by farmers could be another explanation: as farmers are risk seeking for moderate to high-probability losses, it is rational for them to keep on hoping they will incur no loss (along with the risk of a high loss), rather than pay a smaller but certain insurance premium. The case of single peril insurances such as hail insurance is somewhat different. Older than multiperil insurances, most often they have been successfully managed by the private sector (Glauber, 2004; Enjolras and Sentis, 2011). Even if single perils have potentially dramatic consequences on farmer's income, their likelihood is rare and moral hazard behaviour is limited. Thus, insurers have been able to offer low insurance premiums compared to farmers' risk premiums, which is sufficient under EUT to explain participation. However, probability weighting also accommodates the success of single peril insurance, while providing further insights. Single perils like hail are typically high-impact low-probability losses for which farmers are extremely risk averse. Thus, because they have overweighted these perils, farmers may have exhibited more risk aversion than predicted by EUT (and expected by insurance professionals), and have been more numerous to purchase insurance. Another consequence of the overweighting of high-impact low-probability losses on insurance demand was outlined by Kahneman and Tversky (1979), and later by Wakker et al.'s (1997). These studies consider the case of probabilistic insurance, which is an insurance scheme involving little probability that the consumer will not be reimbursed, in exchange for a reduction in the premium. (Wakker et al., 1997, p.7) show that people 'dislike probabilistic insurance and demand more than a 20% reduction in the premium to compensate for a 1% default risk'. In other words, people attach great importance to eliminating the smallest chance of failure. In fact, all insurances are probabilistic, including crop insurances. Most often, the contracts specify some events in which the claim is not to be paid. Moreover, implicit risks such as insolvency or fraud on the insurer' side always exist (Wakker et al., 1997). Thus, the insurers (and the public authorities) should be aware of the high cost of adding exclusion situations in the contracts, or abrading, even slightly, farmers' confidence in the insurance system.

A second research area in which probability weighting has important implications is the design of contracts. Similarly to insurance policies, any real contract setting includes low-probability explicit and implicit default risks leading to losses for the agent. In the case of the supply of some innovative crop (e.g., a crop dedicated to bioenergy production), a failure from the buyer has potentially dramatic consequences on farmers' income because the market for the crop may be still developing, and alternative outlets scarce (Alexander et al., 2011). Thus, the buyer should fully take into consideration this risk to ensure farmers' participation in the contract, even if it may seem insignificant from their point of view. A way of giving the farmer an incentive to grow the new crop would be to substantially increase the crop base price. However, a more effective (and profitable) option for the buyer may be either to reduce the default risk perceived by the farmer or diminish the potential consequences of the risk. For instance, the buyer could provide more information about his commercial strategy and partners in order to enhance farmers' trust (which is costless) or offer a specific insurance (which would be based on objective probabilities).

Price hedging is another domain where probability weighting may be helpful in explaining farmers' behaviour. In developed countries, the gradual elimination of public price regulation and market protection systems have contributed to the increasing price volatility of agricultural commodities. However, surveys report that only few farmers resort to derivative markets to hedge price risk (less than 10% according to Garcia and Leuthold, 2004). Mattos et al. (2008) investigates this paradox by analysing the impact of cumulative probability weighting (as well as utility curvature and loss aversion) on soybean producers' optimal position on the futures market. They find that probability weighting affects this position relatively more than changes in utility curvature and loss aversion. Furthermore, they show that, as probability weighting increases (towards the overweighting of extreme events), the utility of resorting to the purchase of futures decreases quickly.

3.7 Conclusion

In this article, we estimated structural models of risk preferences under EUT and CPT, based on a sample of French farmers, and using real monetary incentives. We also investigated how preferences correlate with several farmer and farm characteristics.

On average, farmers were found to exhibit a concave utility function (which under EUT would mean risk aversion). However, CPT explained farmers' behaviour more fully than EUT in the context of our experiment. Indeed, farmers valued losses twice as much as gains of the same magnitude, meaning loss aversion. In addition, they exhibited an 'inverse S-shape' probability weighting function, meaning that they tended to overweight extreme events, in particular unlikely ones. These results support the suitability of behavioural models such as CPT to better explain and predict farmers' risk behaviour.

We provided detailed examples of applications in the domains of insurance, contract design, market finance, public incentive and innovation adoption. A general recommendation for policy makers and companies would be to differentiate the behaviour of farmers according to gains and losses as well as take into greater consideration extreme events to enhance economic efficiency.

The focus of our study was to highlight the existence of some non-expected utility behaviour among farmers and to overall assess the suitability of CPT. Given these objectives, it was sufficient to assume that the data were generated by only one decision process, either expected utility or prospective utility. Further research could fine-tune our results by estimating a mixture model assuming explicitly that observed behaviour can proceed from different theoretical frameworks, and providing a choice-by-choice assessment Harrison and Rutström (2009); Bruhin et al. (2010).

In addition, other experiments performed on different stakes and frames would be valuable to examine to what extent our results apply to other contexts.

Chapter 4

Adoption of perennial energy crops and behavioral preferences. An empirical investigation among French farmers.

We mix survey and experimental data to investigate the impact of individual risk and time preferences on the adoption of perennial energy crops by farmers in *Bourgogne*, France. Risk and time preferences were elicited in the prospect theory and hyperbolic discounting frameworks respectively. Our results demonstrate that farmers faced with the adoption choice display a different behaviour depending on their degree of loss aversion and probability weighting. The effect of loss aversion is highly dependent on farmers' reference level, which may be related to land type or farm history, and land type. The effect of probability weighting is highly dependent on land type. We find that the more loss averse the farmer, and the more weighted the extreme events, the lower the probability of adoption on plain land. We also show that farm characteristics are relevant factors, the proportion of low-profitability land being a driver of adoption and a cattle-breeding activity a barrier to adoption. Our use of behavioural models to examine technology adoption reveals results that standard decision models cannot provide. More specifically, prospect theory holds promise for deepening our understanding of the process leading to the adoption of perennial plant systems.

Keywords: innovation, marginal land, biomass, decision theory
JEL Codes: C34; Q16; Q12

4.1 Introduction

Today, agriculture faces new challenges, namely ensuring food security in quality, supplying raw material for non-food purpose, and respecting the environment. In this context, perennial crops have received lately a renewed attention (Glover et al., 2010; Schulte et al., 2006; Atwell et al., 2010). Indeed, perennials have advantages over annuals in providing at the same time high yields and important environmental benefits. Due to longer growing seasons and deeper rooting depths, they exhibit a high water and light-use efficiency. Their great root mass has also positive effects on soil quality and stability as well as on carbon sequestration (Hansen et al., 2004; Brandão et al., 2011). Permanent coverage was also shown to benefit to wildlife (Bellamy et al., 2009; Semere and Slater, 2007b). Moreover, perennial crops require few field operations and chemical inputs, which explains their good energy and greenhouse gas balance (McLaughlin and Walsh, 1998; St Clair et al., 2008). These features are particularly valuable for marginal land or where resources are limited.

Perennial crops are used both for food and non-food purpose. The attention has particularly focused on non-food crops because of the strategic and environmental interest of replacing petroleum-based products, and especially on perennial energy crops because of the huge volume and value at stake. Actually, this sector is strongly supported by both European and U.S. policies. In the case of the European Union, challenging biofuel targets have been established in the short-term: a 10 % share of energy from renewable resources in transport by 2020 (European Union, 2009). To achieve the objective, second-generation biofuels from cellulosic material are clearly encouraged over biofuels from food crops, because they proved to disturb food markets and have poor economical and environmental performances. Among the likely cellulosic biomass sources, perennial energy crops are repeatedly cited as very promising (Smeets et al., 2009; Rowe et al., 2009; Lewandowski et al., 2003; Sultana and Kumar, 2012).

However, the issue of the competition of perennial energy crops with food crops for land and water resources is strongly debated. It will raise more and more sharply while food needs are increasing and chemically intensive farming is diminishing (Smith and Moore, 2010). Moreover, direct and indirect land-use change induced by the expansion of energy crops can result in carbon debt and biodiversity loss if land with high carbon stock and high biodiversity value is to be altered (Havlík et al., 2011). Thus, a careful investigation of factors driving farmers' willingness to grow perennial crops is needed to quantify the potential food and non-food biomass supply, assess the ensuing economic and environmental outcomes, and identify relevant policy designs.

A growing number of authors has conducted investigations to explain why farmers adopt (or would adopt) perennial crops in their farming systems. Farm-level cost studies are by far the most numerous, especially those concerned with perennial energy crops (e.g., Downing and Graham (1996), Duffy and Nanhou (2002), Monti et al. (2007) for switchgrass and Styles et al. (2008), Smeets et al. (2009) for miscanthus). They provide break-even output prices according to different price, yield and discounting scenarios. They generally conclude that perennial crops can be competitive with traditional annual crops only under restrictive conditions. Some authors also developed whole-farm economic analyses to take into account the competition for the farm resources. For instance, Byrne et al. (2010) and Bell et al. (2008) focused on the value of perennial wheat in Australian dryland agricultural systems. Bathgate and Pannell (2002) studied lucerne adoption in the context of on-farm salinity prevention in Australia. Sherrington and Moran's (2010) study is a recent application to willow short-rotation coppice and miscanthus in the united Kingdom. A few researchers also led field surveys to investigate a wider range of factors, besides the pure economic ones. See for instance the work by Jensen et al. (2007), Villamil et al. (2008) or Qualls et al. (2012) about switchgrass and miscanthus in the United States, and by Roos et al. (2000), Sherrington et al. (2008) or Rämö et al. (2009) about short-rotation coppice and miscanthus in northern Europe. Common factors identified as influencing the adoption of perennial crops in this empirical literature include profitability, farm size, human capital (age, eduction, moral and social concerns), resource and technical constraints, access to information, triability.

Surprisingly, risk issues have been largely overlooked in the aforementioned studies. As noted by Feder et al. (1985), and later by Marra et al. (2003), there is a general lack of individual adoption studies that have adequately addressed the role of risk in adoption, probably due to the difficulties in observing and measuring risk. Nevertheless, risk factors have been repeatedly shown to be key elements in understanding the adoption process in many contexts (e.g., Koundouri et al., 2006; Serra et al., 2008; Just and Zilberman, 1983; Abadi Ghadim et al., 2005), and, as such, they are expected to be also relevant in the case of perennial crops. In addition, because it takes several years before the return on investment is positive, the long-term profitability of perennial crops is particularly uncertain to farmers (Sherrington et al., 2008; Villamil et al., 2008; Pannell, 2001b). Indeed, the economic and legal environment is highly variable, whereas up-front costs can be quite large.

Furthermore, perennial energy crops raise some new interesting issues for risk analysis. First, perennial energy crops are usually sold under production contracts which guarantee a long-term output price (Chapter 1, Chapter 2 and Alexander et al. (2011)), and thus considerably decrease the perceived risk. Second, despite those contracts, production or market accidents such as an establishment failure or a counterparty failure do exist, and can result in extreme income losses. In their survey of northern American farmers, Smith et al. (2011) reported that the risk of unsuccessful establishment was one of the most important perceived barriers to growing perennial energy crops. Third, the resistance of perennial species make them relatively profitable and unrisky compared to annual crops and pastures if growing conditions are not good. On the contrary, in good growing conditions, perennial energy crops are expected to be less profitable than traditional land uses. Thus, crop location is important when comparing the attractiveness of perennial energy crops with competing land uses.

The handling of time issues in the literature about perennial energy crops is also insufficient. In most cases, standard discount rates are actually integrated into net present value calculations, but dynamic phenomena and return irregularities over time have received a poor attention so far, despite their central role in the valuation of perennial systems. Return irregularities are particularly significant in the short-term, as high up-front costs are followed by a lengthy establishment period with only costs and no benefits.

There are two noteworthy exceptions to the scarcity of risk and time analyses applied to perennial energy crops. Chapter 1 is one of them. The authors built a stochastic farm model to quantify the effect of price risk and farmers' risk preferences on the extent of miscanthus and switchgrass adoption in French cereal farms. They showed with an expected utility approach that diversification effects, especially if the long-term price of the perennial crop is guaranteed by a production contract, can be powerful incentives to adoption. In addition, because farmers are averse to intertemporal fluctuations, the authors highlighted the positive effect on adoption of smoothing returns over time. Song et al. (2011) is the second exception. Using a real option framework, they studied the patterns of land conversion into and out of perennial energy crops over time. Applying their model to switchgrass in the United States, they highlighted the significant option value of delaying land conversion to reduce uncertainty, even when a static net present value threshold is passed. However, the value of these two studies is mainly normative.

The aim of this paper is to clarify the relationship between the adoption of perennial energy crops and farmers' individual risk and time preferences. The empirical analysis is based on a cross-sectional sample of French farmers. We make three contributions to the adoption literature. First, we mix survey data with experimental preference data. The survey data include a wide range of farm and farmer characteristics which are used as explanatory variables in a multivariate analysis of real adoption along with the experimental measures of preferences. By resorting to experimental data, we avoid the hypothetical bias inherent to most empirical adoption studies which usually rely on stated data when incorporating some preference measure (Cardenas and Carpenter, 2007).[1] We also believe our results to be more accurate than those from other adoption studies about perennial energy crops because we rely on an actual adoption decision.[2]

Second, we extend the usual risk and time studies based on the standard expected utility and exponential discounting frameworks to take into account extreme events and short-term discounting. Under expected utility theory, farmers value a perennial energy crop depending on objective probabilities. However, faced with unfavorable extreme events, they may be particularly reluctant to adopt the crop, similar to the predictions of Tversky and Kahneman's (1992) prospect theory (PT). Under exponential discounting, farmers discount the short-term outcomes and the long-term outcomes at the same rate. In other words, in the case of a perennial energy crop, the costs incurred during the establishment period (excluding the initial investment) and the profits far into the future are discounted at the same rate. But, in fact, farmers may discount outcomes in the near future at a higher rate than in the far future, as predicted by Loewenstein and Prelec's (1992) hyperbolic discounting (HD). Hence, they may put less weight on the short-term costs of perennials and more weight on their long-term benefits than under constant discounting. As a consequence, the burden of the establishment period may not be as critical as usually argued. Prospect theory and hyperbolic discounting have been widely applied

1. Studies mixing survey and experimental data are rather uncommon in agricultural economics. The seminal paper by Binswanger (1980) is an early attempt to explain farming decisions with experimental risk-aversion measures. Liu and Huang (2011), Barham et al. (2011), Bauer et al. (2012), and Nguyen and Leung (2009) are other recent examples relative to farmers' decision making.

2. To our knowledge, Roos et al. (2000) is the only previous study not relying on hypothetical adoption decisions.

in the financial literature, but seldom in the agricultural literature.

Third, we contrast the effect of risk preferences on adoption depending on land type. Because farmers may value the attractiveness of perennial energy crops relative to the *status quo*, they may perceive perennial energy crops as a sure income loss, relative to annual crops, on land where growing conditions are favorable, and a sure income gain, relative to annual crops, on land where growing conditions are unfavorable. Farmers being risk-seeking for losses and more sensitive to losses than gains (Chapter 3), farmers may be more reluctant to allocate plain land to perennial energy crops than forecasted by expected utility theory. Prospect theory accommodates this kind of reference-dependent behavior.

Shedding light on how risk and time preferences influence the adoption of perennial energy crops may help energy producers to propose efficient contracts to secure the supply. It may also give governments insights about how public incentives could be designed to make perennial energy crops a credible and sustainable energy source.

This paper is organized as follows. In Section 4.2, we present the theoretical frameworks underlying our analysis. In Section 4.3, we describe the land allocation model for the adoption decision. The data are described in Section 4.4. In Section 4.5, we specify the empirical adoption models. The results are presented in Section 4.6. Section 4.7 concludes and highlights policy implications.

4.2 Theoretical background

In the field of agricultural economics, and notably in adoption studies, risky and intertemporal decisions have been mostly analyzed in the light of standard rational choice theories, respectively von Neumann and Morgenstern's (1947) expected utility (e.g., Feder and O'Mara, 1981; Just and Zilberman, 1988) and Samuelson's (1937) discounted utility. On the contrary, our empirical strategy is based on predictions drawn from behavioral decision models. Indeed, since the pioneering work by Simon (1955, 1956) introducing the concept of bounded rationality, it is recognized that cognitive, emotional and social biases strongly influence behavior, leading to changing and unstable preference functions. Behavioral models adapt traditional normative models of decision making by explicitly incorporating the systematic errors made by decision makers. Such descriptive models have been repeatedly shown to better account for the observed behavior than the standard rational approaches. In this section, we describe the main features of propsect theory (PT) and hyperbolic discounting (HD), two behavioral models which proved to convincingly depict risk and time preferences respectively.

4.2.1 Prospect theory for risky choices

In Tversky and Kahneman's (1992) PT framework, agents are assumed to make choices so as to maximize a *prospective value.* Four features distinguish cumulative PT from expected utility theory.

– First, decision makers view outcomes as *changes in wealth* rather than absolute wealth levels (asset integrated into final wealth). These changes are defined respective to a *reference point*, qualified as labile because it depends on decision makers' expectations and norms, as well as circumstances (framing). Usually, the reference point corresponds to the *status quo.*

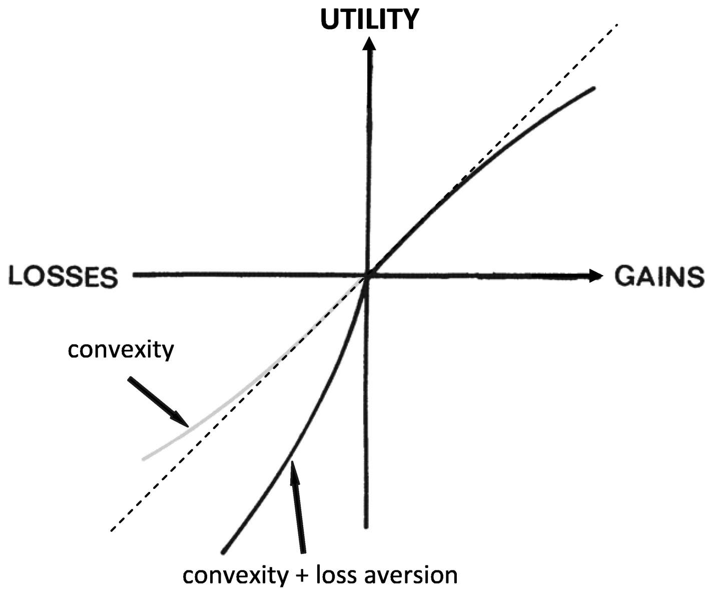
– Second, decision makers exhibit a diminishing sensitivity to outcomes as they deviate from the reference point. In other words, agents are more sensitive to a wealth change close to the reference point than far away from it. Thus, the *value function* [3] for outcomes is usually concave above the reference point and often convex below it (see Figure 4.1 for an illustration).

– Third, decision makers classify outcomes as either gains or losses relative to the reference point in an *editing phase.* This phase is preliminary to the *evaluation phase* in which the value of the prospect under assessment is computed. Their behavior is different in each of the two outcome domains, losses looming larger than gains because of *loss aversion.*

– Fourth, it is explicitly assumed that agents distort objective probabilities into subjective probabilities non-linearly, through a *probability weighting function.* Again, diminishing sensitivity applies and the strength of the distortion decreases as probabilities and outcomes go away from extreme values. [4] It was empirically shown that individuals tend to be

3. To emphasize the difference between expected utility and PT, Tversky and Kahneman (1992) used the term *value function* instead of *utility function.*

4. The notion of extreme outcomes only exists in the *cumulative* version of PT (Tversky and Kahneman, 1992). As shown later, in cumulative PT, the weighting function applies to cumulative probabilities rather than single probabilities, the latter being the rule in Kahneman and Tversky's (1979) *separable* (or *original*) version of PT. Contrary to separable PT, cumulative PT satisfies stochastic dominance and can be applied to prospects with a large number of outcomes (Tversky and Kahneman, 1992). This is the version we consider throughout this paper.



Source: adapted from Kahneman and Tversky (1979)

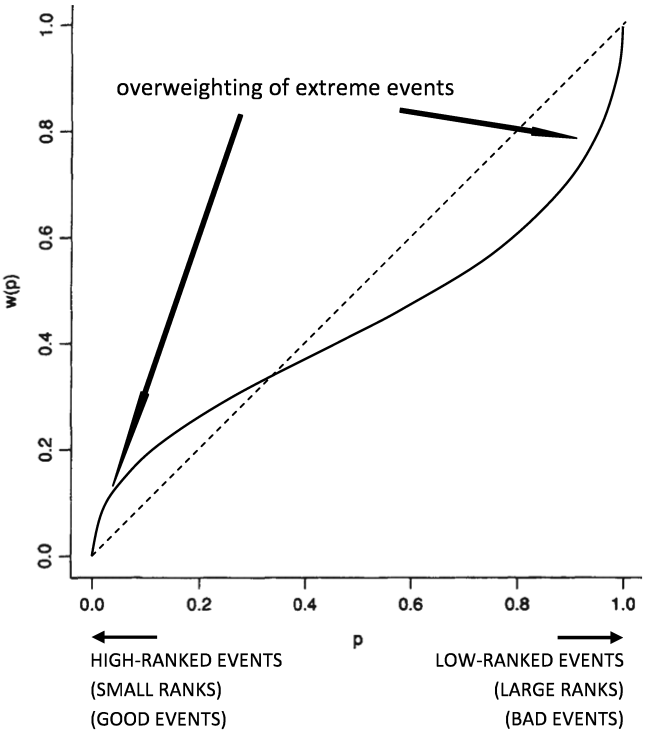
Figure 4.1: Common shape for the value function under PT

more sensitive to a probability change close to the extreme values 0 and 1 than in the middle range. Thus, the weighting function commonly displays an 'inverse S-shape' (see Figure 4.2 for an illustration).

Overall, in PT, risk behavior results from the interplay of these four phenomena, namely reference dependence, curvature of the value function, loss aversion and probability weighting. The resulting empirical finding is risk aversion in the domain of (moderate and high) gains but risk seeking in the domain of (moderate and high) losses. By contrast, expected utility theory features only one preference parameter, utility curvature, which describes totally the risk behavior. Under this standard framework, individuals are found to be risk-averse whatever the outcomes at stake.[5]

Formally, under PT, any risky prospect defined by a set of monetary outcomes y_i with associated probabilities p_i can be written $(y_{-m}, p_{-m}; \ldots; y_i, p_i; \ldots; y_n, p_n)$, where gains are denoted by positive numbers $(0 < i < n)$ and losses by negative numbers $(-m < i < 0)$. The

5. More precisely, the usual finding under PT is a four-fold pattern of behavior: risk aversion for moderate and high-probability gains, risk seeking for moderate and high-probability losses, risk seeking for small-probability gains, risk aversion for small-probability losses. This pattern is sometimes referred to as 'S-shape preferences'. By contrast, under expected utility, the behavior pattern is two-fold: risk neutrality for small stakes and risk aversion for high stakes (Tversky and Kahneman, 1992).



Source: adapted from Tversky and Kahneman (1992)

Figure 4.2: Common shape for the probability weighting function under cumulative PT

value of such a prospect is calculated as follows in a so-called *evaluation phase*:

$$PV(y_{-m}, p_{-m}; ...; y_n, p_n) = \sum_{i=-m}^{n} \pi_i.v(y_i) \tag{4.1}$$

where $v(.)$ is the decision maker's utility function, satisfying $v(y_0) = 0$, $v''(y) < 0$ for $y > y_0$ and $v''(y) > 0$ for $y < y_0$, and π_i is a *decision weight* applied to each of the $n + m + 1$ potential outcomes. Compared to expected utility, in this expression, the shape of v is different for gains and for losses, and objective probabilities are replaced by decision weights. These weights result from the transformation of objective probabilities by a non-linear weighting function $\omega(.)$ (see Figure 4.3). If in $(y_{-m}, p_{-m}; \ldots; y_i, p_i; \ldots; y_n, p_n)$ outcomes are arranged in increasing order , then cumulative decision weights are defined by [6]:

$$\pi_i = \begin{cases} \omega^+(p_i + \ldots + p_n) - \omega^+(p_{i+1} + \ldots + p_n) & \text{if } 0 \leq i \leq n-1 \\ \omega^-(p_{-m} + \ldots + p_i) - \omega^-(p_{-m} + \ldots + p_{i-1}) & \text{if } 1-m \leq i < 0 \\ \omega^+(p_n) & \text{if } i = n \\ \omega^-(p_{-m}) & \text{if } i = -m \end{cases} \tag{4.2}$$

where $\omega^+(.)$ and $\omega^-(.)$ are strictly increasing functions from the unit interval into itself, satisfying $\omega^+(0) = \omega^-(0) = 0$, and $\omega^+(1) = \omega^-(1) = 1$.

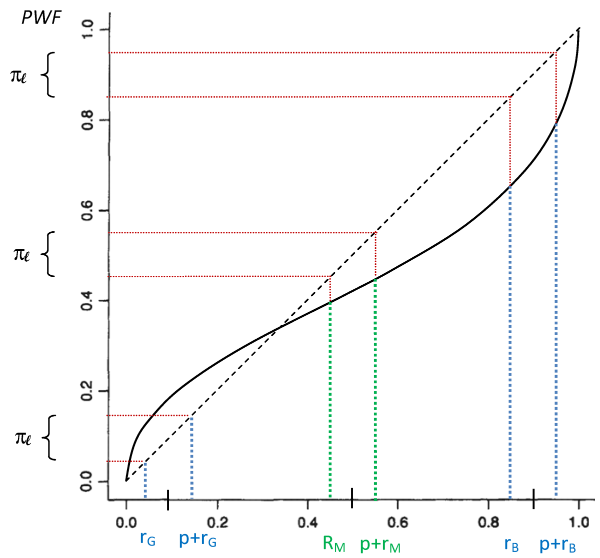
4.2.2 Hyperbolic discounting for intertemporal choices

Empirical observations also shed light on several anomalies of the discounted utility model (see Frederick et al. (2002) for a review), in particular declining discount rates over time rather than constant discount rates. In this study, we account for this anomaly by assuming that hyperbolic discounting (HD) (Loewenstein and Prelec, 1992) drives farmers' intertemporal choices. Similarly to PT, HD '*assumes that intertemporal choice is defined with respect to deviations from an anticipated* status quo *(or 'reference') consumption plan; this is in explicit contrast to the DU assumption that people integrate new consumption alternatives with existing plans before making a choice*' (Loewenstein and Prelec, 1992).

Hyperbolic discount functions are characterized by a relatively high discount rate over short horizons and a relatively low discount rate over long horizons (see Figure 4.4 for an illustration). Formally, the value of a dated sequence of monetary outcomes $(y_0, t_0; \ldots; y_i, t_i; \ldots; y_n, t_n)$ can

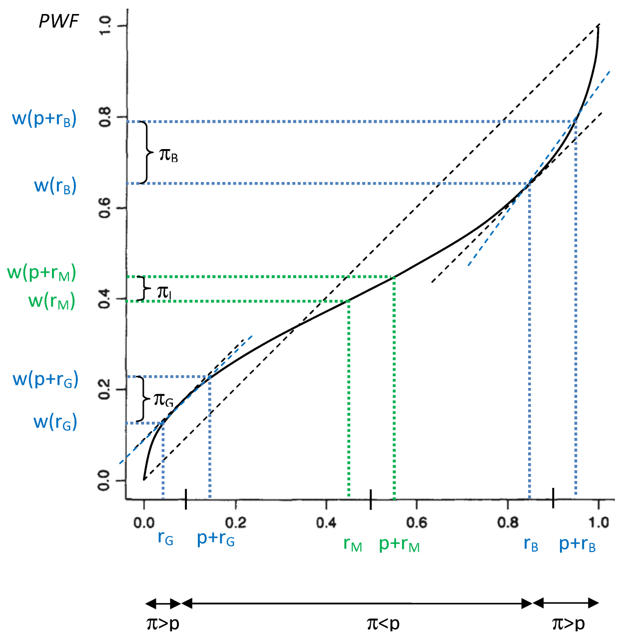
6. In cumulative PT, the probability weighting function operates on the *rank* of outcomes, defined as the probability of receiving an outcome that is higher (ranked better) (Wakker, 2010). Thus, good outcomes have small ranks and bad outcomes large ranks. With our notations, the rank of any y_i would be $p_{i+1} + \ldots + p_n$ if $0 \geq i \geq n-1$, and 0 if $i = n$.

Let us consider a good outcome G with probability p and rank r_G, a bad outcome B with probability p and rank r_B, and an medium outcome M with probability p and rank r_M. With a linear PWF, whatever the outcome, decision weights (π_ℓ) are equal to p.



(a) Linear PWF

With an inverse S-shaped PWF, the decision weights of extreme ranked events (π_G and π_B) are higher than p, and those of medium events (π_M) are lower than p. The decision weights of extremely bad ranked events are higher than those of extremely good ranked events ($\pi_B > \pi_G$).



(b) Inverse S-shape PWF

Figure 4.3: Transformation of cumulative probabilities into decision weights for positive outcomes

be written [7]:

$$HV(y_0, t_0; \ldots; y_n, t_n) = \sum_i D(t_i).y_i \quad (4.3)$$

where $D(.)$ is the decision maker's hyperbolic discount function, which depends on the time period and satisfies $D(0) = 1$. The preferences given by Equation (4.3) are dynamically inconsistent, in the sense that preferences at date t are inconsistent with preferences at date $t+1$ (the marginal rate of substitution between periods $t+1$ and $t+2$ is lower at date $t+1$ than at date t).

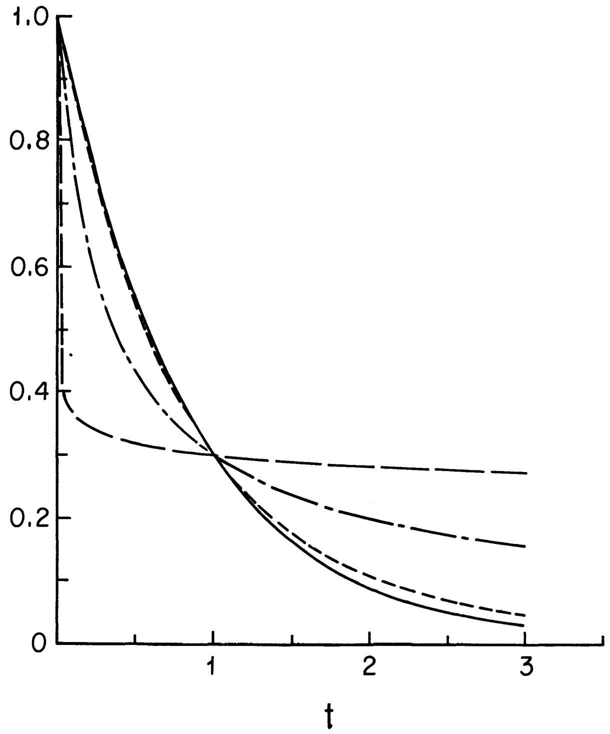
4.3 Land allocation model and hypotheses

4.3.1 Portfolio setting

The adoption of miscanthus at the farm-level can be viewed as the solution of a portfolio problem [8] where land has to be allocated to competing divisible technologies (Feder and O'Mara, 1981; Just and Zilberman, 1988). For simplicity, only two technologies are available to the farmer: a traditional one (denoted by an index j of 0), such as a cereal crop, and an innovative one (denoted by an index j of 1), a perennial energy crop. Each technology generates an annual stochastic payoff $r_j(t)$ (per unit area) which aggregates over the planning horizon T into a stochastic return, depending on the amount of land α_j allocated to the given technology. The allocation variables do not vary over time. We assume that the aggregation follows the HD rule described in Section 4.2.2. Indeed, the experiment we led on the farmers sampled in this paper

7. More precisely, this expression corresponds to a net present value under hyperbolic discounting and not to the hyperbolic discounting model. In the latter, instantaneous utility functions are involved and the discount function applies to utils rather than to monetary outcomes. The model we consider here is to the HD model as the standard net present value is to the discounted utility model. However, the financial net present value is often used as an approximation of the original utility calculations. To derive the net present value from the original models, one needs to make three assumptions (Frederick et al., 2002). First, monetary outcomes are instantaneously consumed by the decision maker, meaning that monetary streams are in fact consumption streams. Second, decision makers ignore the opportunity for intertemporal arbitrage through capital markets. Third, utility is linear. Although the net present value approach is very common in experiments aiming at eliciting discount rates (e.g., Coller and Williams, 1999), in most of them these assumptions are implicit. It is probably because they are easily confirmed under expected utility which is the usual framework for preference elicitation. Whereas the first two assumptions may be also valid under non-expected utility frameworks, the assumption of utility linearity is more questionable when there is some reference dependence (Frederick et al., 2002). Indeed, under the expected utility framework, and in the absence of risk, utility is approximately linear over small amounts (Rabin, 2000; Andersen et al., 2008), which is not the case when outcomes are framed as changes from a reference point. Hence, our experimental measures of discount rates (resp. discount factors) may be slightly overestimated (resp. underestimated).

8. Originally designed by Markowitz (1952) to explain investment in financial securities, portfolio models are widely used in agricultural economics to model production choices at the farm-level.



Source: Loewenstein and Prelec (1992)

Figure 4.4: Hyperbolic discount functions (dashed lines) compared to the corresponding exponential discount function (full line)

showed that HD explained their preferences over temporally dated income options better than constant discounting. Payoffs from the cereal crop do not depend on the time period. Thus, the intertemporal stochastic return from the cereal crop is :

$$HV_0 = \alpha_0 . \sum_t D(t).r_0 \qquad = \alpha_0 . x_0 \tag{4.4}$$

and the one from the perennial crop is:

$$HV_1 = \alpha_1 . \sum_t D(t).r_1(t) \qquad = \alpha_1 . x_1 \tag{4.5}$$

where $D(.)$ is the farmer's hyperbolic discount function, which satisfies $D(0) = 1$, and x_i the intertemporal stochastic return of crop i per unit area.

We further assume that the representative farmer behaves as a cumulative PT maximizer. Indeed, we showed experimentally that the farmers in the sample exhibited PT rather than EUT when faced with risky choices (see Chapter 3). Following the PT described in Section 4.2.1, the farmer Θ cares about the following farm-level stochastic income:

$$y_\Theta = \sum_j \alpha_j . x_j - \ell_\Theta \tag{4.6}$$

which is defined relative to farmers' reference point ℓ_Θ. Thus, the farmer's problem is to select the land areas α_j so as to maximize the following prospective value :

$$PV = \sum_{y_\Theta} \pi_{y_\Theta} . v(y_\Theta) \tag{4.7}$$

where π_{y_Θ} is the decision weight applied to the farm income y_Θ, and v is the farmers' value function. The maximization is constrained by the total amount of land L which is fixed. Land fixity is a reasonable assumption in the short-term. Land is also assumed to be fully used. Hence, the land constraint can be written:

$$\sum_j \alpha_j = L, \qquad \alpha_j \geq 0 \qquad \forall j. \tag{4.8}$$

We build up a variant to this model by considering heterogeneous land resources. Land is either *plain* (also referred to as *regular* or *non-marginal*) or *marginal*. Marginal land refers to land where traditional crops give significantly lower per hectare returns than the rest of the farm land. In this context, choice variables are doubled: the representative farmer decides how much plain land to allocate to each technology, and also how much marginal land to allocate to each technology. Two options may be considered for the modeling of this extended portfolio problem. On the one hand, it could be hypothesized that farmers assess allocation options as a group. It means that they take into consideration the covariance between all payoffs, and assess the allocation options relative to a unique reference point. On the other hand, it is also relevant to suppose that farmers focus on the outcomes of plain-land allocation and marginal-land allocation separately.[9] In this case, only the covariance between payoffs from the

9. In the risk and psychological literature, this segregation of outcomes is known as *narrow framing*. Just like the coding of outcomes in gains or losses, it is a mental operation that can occur in the editing phase of PT. It is defined by Kahneman and Lovallo (1993) as the fact that '*people tend to consider decision problems one at a time, often isolating the current problem from other choices that may be pending, as well as from future opportunities to make similar decisions*'. More precisely, we refer here to *cross-sectional narrow framing*, as called by Thaler et al. (1997) for distinction with *intertemporal narrow framing* . A financial definition of *cross-sectional narrow framing* would be '*the tendency to treat individual gambles separately from other portions of wealth. In other words, when offered a gamble, people often evaluate it as if it is the only gamble they face in the world, rather than merging it with pre-existing bets to see if the new bet is a worthwhile addition*' (Barberis

same type of land is accounted for, and the reference point may differ from one land type to the other. Indeed, as outlined by Wakker (2010), the reference point is labile, and varies with circumstances and individual expectations and norms. In this paper, we opt for the second option because it is highly probable that farmers do not have the same performance expectations for crops grown on plain land than for crops grown on marginal land. By doing so, one may argue that we underestimate the positive impact of uncorrelated risks on miscanthus adoption (see the diversification effect described in Chapter 1). However, in PT framework, it is less problematic that under expected utility framework because diversification effects are clearly less prominent: decision makers often prefer to concentrate risks so as to keep low the potential for small losses, even if at the same time they keep high the potential for large losses. This is due to both their risk-seeking behavior in the loss domain and their aversion to losses compared to gains (Stracca, 2002; He and Zhou, 2011; Bernard and Ghossoub, 2010). As a consequence, the adoption model can be viewed as a double portfolio problem. The representative farmer selects the land areas α_j and β_j so as to maximize the following prospective values:

$$\begin{cases} PV_P = \sum_{y_\Theta} \pi_{y_\Theta}.v(y_\Theta) & (4.9a) \\ PV_M = \sum_{z_\hbar} \pi_{z_\hbar}.v(z_\hbar) & (4.9b) \end{cases}$$

subject to:

$$\sum_j \alpha_j = P, \qquad \sum_j \alpha_j = M, \qquad \alpha_j, \beta_j \geq 0 \qquad \forall j$$

where y_Θ and $z_\hbar$ are the total stochastic incomes from plain and marginal land respectively, defined in relation to land-specific reference levels Θ and $\hbar$, α_j and β_j are the surface areas allocated to crop j on plain and marginal land respectively, and P and M are the total plain and marginal land areas$(M + P = L)$.

and Thaler, 2003). The consequence for portfolio problems is a concentration of risks because PT investors ignore the covariance between assets and the benefits of diversifying when it is low. The equity premium puzzle, i.e., the low level of diversification in stockholders' portfolio, is one famous empirical example of concentrated portfolios (see e.g. Shefrin and Statman, 2000). *Intertemporal narrow framing*, which is not accounted for in this paper, implies short evaluation periods, either because subjects evaluate assets frequently or because they have a short planning horizon. This is known as a *myopic* behavior. Because of the piece-wise form of the value function, myopic investors have a higher probability of observing a small gain, as well as a higher probability of observing a small loss than non-myopic investors. Thus, myopia increases the attractiveness of risky assets in the gain domain and decreases it in the loss domain. Yet, as investors are usually loss averse, they are likely to mostly focus on the losses. As a consequence, subjects exhibiting a *myopic loss aversion* are expected to be less willing to take risks than the others (Benartzi and Thaler, 1995; Thaler et al., 1997).

The coding of outcomes as changes in wealth relative to a *reference point* occurs in the *editing phase*. Although not grounded in any theory, a widespread assumption states that the reference point corresponds to the *statu quo*. But, as outlined by Kahneman and Tversky (1979), '*there are situations in which gains and losses are coded relative to an expectation or aspiration level that differs from the status quo*'. In the context of the adoption of a new crop, it is reasonable to think that the reference level is either the mean return from the land use which is to be changed if the adoption occurs (statu quo), or another amount most probably linked with the farm history (expectation level). In our problem, we consider these two options for plain land: the reference point can be the mean return from the cereal crop ($\ell_\Theta = \overline{x_0}$), or, due to specific circumstances, a much higher or lower value ($\ell_\Theta >> \overline{x_0}$ or $\ell_\Theta << \overline{x_0}$). For marginal land, we assume that the reference point can only be the mean return from the cereal crop on this type of land ($\ell_\Theta = \overline{z_0}$).

Developing the prospective value in Equation (4.10a) (or in Equations (**??**)and (4.9b)), we can explicitly distinguish positive outcomes from negative outcomes (relative to the given reference point). Because $v'(y_\Theta) > 0$ for any y_Θ, $v(\ell_\Theta) = 0$, and $v(y_\Theta) < 0$ when $y_\Theta < 0$, we obtain:

$$PV = \sum_{y_\Theta > 0} \pi_{y_\Theta}.v(y_\Theta) - \sum_{y_\Theta < 0} \pi_{y_\Theta}.|v(y_\Theta)| \tag{4.10a}$$

$$= PV^+ - PV^- \tag{4.10b}$$

where PV^+ is the prospective value for gains and PV^- is the prospective value for losses. They can be interpreted as the *upside potential* and the *downside potential* of the crop mix. The optimal allocation decision is the one that maximizes the difference between the upside and the downside potential (Stracca, 2002; He and Zhou, 2011; Bernard and Ghossoub, 2010).

The upside and the downside potential are positive subjective values which depend, on the one hand, on farmers' tastes, which are captured by the curvature of their value function and the strength of their loss aversion, and, on the other hand, on farmer's perceptions of income distributions, which are captured by the reference point and the strength of the probability distortion. In the next section, we make further assumptions relative to crop returns, and review the implications of PT preferences on the land-allocation decision under such assumptions.

Indeed, returns of perennial crops differ from those of annual crops in the time pattern of the expected amounts and in the probability distribution of intertemporal amount.

4.3.2 Crop returns: time pattern and probability distributions

In this section we complete the description of the adoption model by characterizing crop returns and reviewing the expected impact of preference parameters on the optimal α_1 and β_1. [10].

Time pattern and effect of time preferences on adoption

Perennial species have typically an irregular payoff pattern over time. Indeed, important plantation costs are incurred on the first year, while harvesting begins on the second or third year only. Meanwhile, some extra establishment costs are needed, for weed control for instance. Figure 1.1 of Chapter 1 provides an illustration of the payoff patterns of wheat and miscanthus. It is well-known that standard constant discounting is unfavorable to such patterns, because benefits that are received in the future are strongly underweighted compared to costs that are concentrated in the first years. However the effect of HD is more complex. As far as the long-term discount rate is concerned, the effect of discounting on the relative attractiveness of the cereal and the perennial crop is the same. The higher the long-term discount rate, the larger the difference between the intertemporal value of cereal returns (Equation (4.4)) and that of perennial returns (Equation (4.5)), and the lower the land allocated to the perennial crop. However, in the short-term, the higher the discounting *ceteris paribus*, the higher the area dedicated to the perennial crop. This is because short-term corresponds roughly to the second and third years of the establishment period [11], when only costs are incurred. In other words, in the case of perennials, only costs of are discounted at a higher rate, whereas in the case of

10. The optimal α_1 and β_1 cannot be derived analytically from the prospective value function in Equations (4.10a) and (4.9) as the first and second order conditions cannot be solved in closed form. Indeed, in comparison to standard expected utility or mean variance portfolio models, in PT models the value function is non-concave and non-smooth and the probability weighting function generates non-linearity with respect to the probabilities. As a result, the prospective value function may have several local maxima, and PT models cannot be solved with common optimisation techniques which look for a global optimum (He and Zhou, 2011). Numerical analyses are thus valuable alternatives (e.g., Gomes, 2005; Berkelaar and Kouwenberg, 2004). Nevertheless, recently, some authors developed noteworthy analytical approaches to solve simple portfolio models under cumulative PT (see Bernard and Ghossoub (2010) and He and Zhou (2011) for a static, one-period setting, and Berkelaar and Kouwenberg (2004) and Jin and Zhou (2008) for a dynamic, continuous-time setting).

11. The plantation costs incurred on the first year are not impacted because $D(0) = 1$.

annuals, costs and benefits are impacted at the same time. [12],

Probability distribution

Like all crops, the probability distributions of cereals and perennials are dependent on the type of land where they are grown. However, because their biological cycles are fundamentally different, their needs in terms of field operations and their response to a change in pedo-climatic conditions are highly contrasted. Depending on the land type considered, their relative economic performances may even be inverted. It is the possibility we explore in this paper.

Generally, average profit calculations tend to conclude that cereal crops are more profitable than perennial crops (see for instance Monti et al. (2007), Deverell et al. (2009), and Chapter 1 in the case of energy crops). However, most of them use yield and cost data corresponding to regular growing conditions. On the contrary, on marginal land, it is likely that perennials are, on average, the most profitable ones. If land is qualified as marginal because of an isolated location or a quirky plot shape, cereal costs increase much more than perennial costs because of the huge difference in the number of field operations. If it is because of unfavorable pedo-climatic conditions, yield losses on cereals are much higher than yield losses on perennials, because of the resistance of the latter to poor soil conditions, drought and frost. As a result, in our problem, the mean return of the perennial crop is assumed to be lower than that of the cereal crop on plain land, but higher on marginal land ($\overline{x_1} < \overline{x_0}$ and $\overline{z_1} > \overline{z_0}$). [13] Crop-by-crop mean returns are all higher on plain land than on marginal land ($\overline{x_0} > \overline{z_0}$ and $\overline{x_1} > \overline{z_1}$).

Crop differences in resistance to drastic growing conditions also have implications on the distribution of returns around the mean: the production risk on perennials is lower than that on cereals, especially on marginal land. In addition, commercial perennials such as energy crops are most often grown under long-term supply contracts which guarantee to farmers a fixed price throughout the crop life-span and offer some technical advice (Chapter 2 and Alexander et al. (2011)). As a result, price risk and technical risk, which are critical for a crop sold on a new market and still unknown by farmers are transferred to the processing industry. By contrast, food-crop prices are increasingly variable, due to more and more volatile international markets.

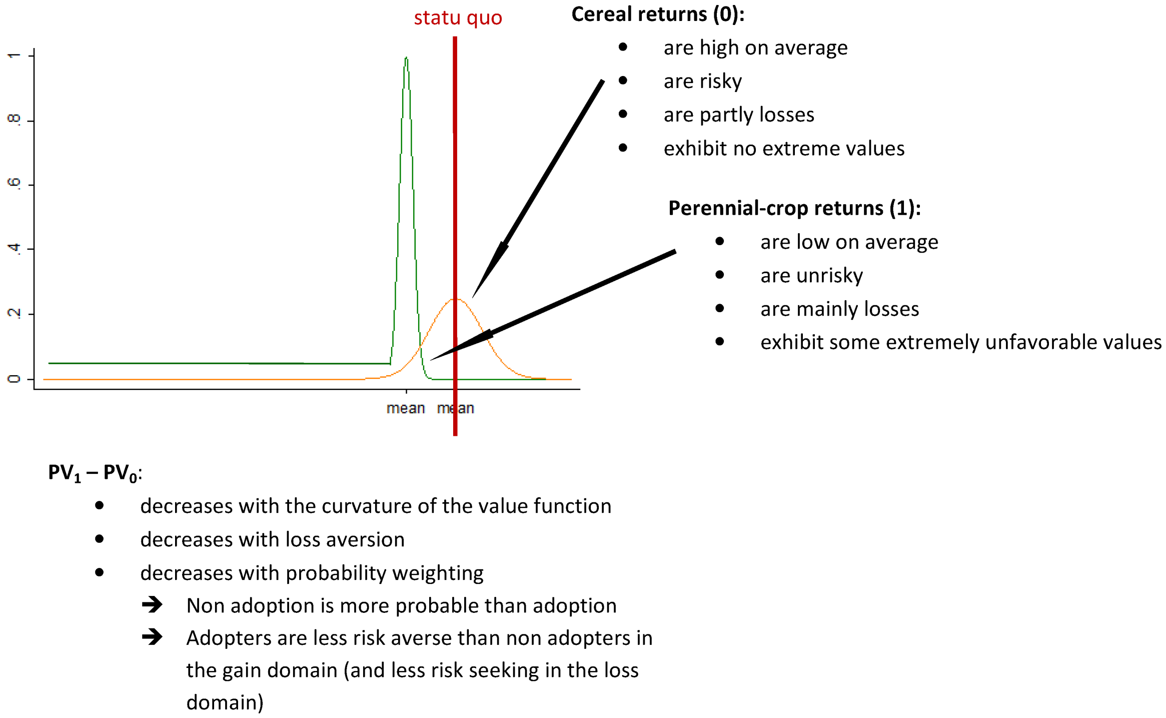
12. Generally speaking, because of very high short-term discount rates compared to long-term discount rates, HD is much more favorable to projects with immediate costs but benefits that are received in the distant future than constant discounting. Global warming abatement is another example of such projects.

13. van der Hilst et al. (2010) validated this assumption in the Dutch context: they found that, on less suitable soils, perennial crops achieve better net present values than common rotations.

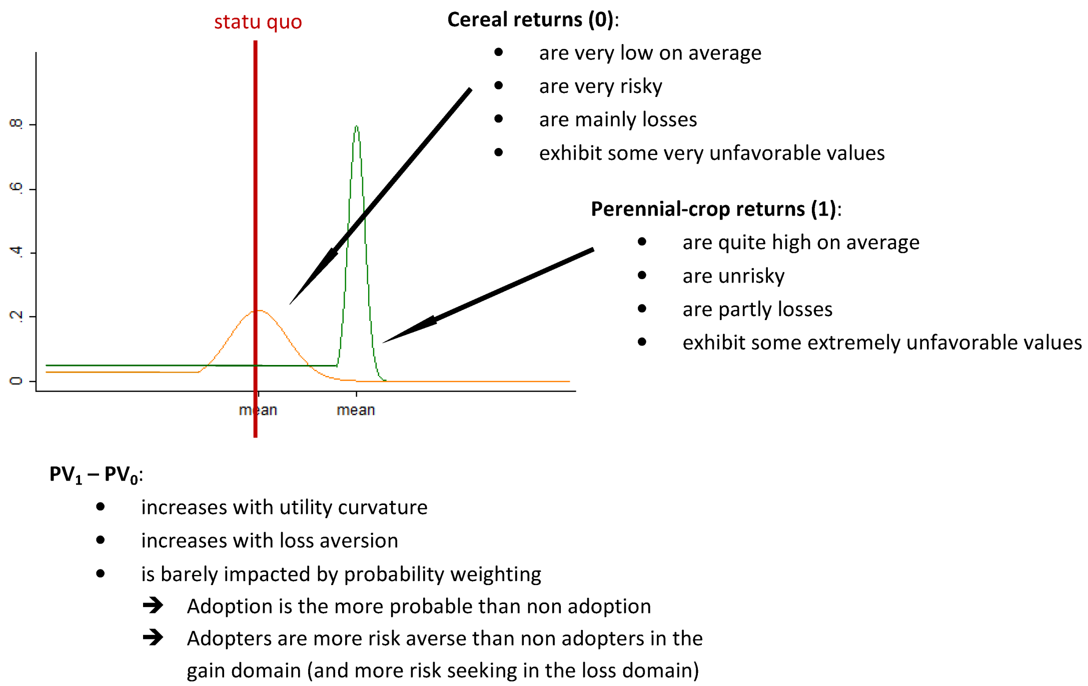
It was shown in Chapter 2 that farmers did perceive production, price and technical risks to be lower on miscanthus than on wheat. A few other studies confirmed the fact that farmers viewed perennial crops as non risky. As a consequence, in our problem, perennials are modeled as risk-reducing innovations, especially if grown on marginal land. The variance of perennial returns is supposed to be much lower than that of cereal returns, whatever the type of land ($var(x_1) << var(x_0)$ and $var(z_1) << var(z_0)$), and the difference in variance is more marked on marginal land than on plain land ($var(z_0) - var(z_1) > var(x_0) - var(x_1)$).

We now wish to focus on a component of probability distributions which is often overlooked in risk assessment, the extreme events which are contained in the distribution tails. Because they are very unlikely and proportionally little-impacted by the utility function, in the standard expected utility framework, their role on the risk behavior is low. By contrats, in cumulative PT, extreme outcomes are overweighted, and this psychological effect can have important consequences on the risk behavior, especially when the extreme outcomes are far from the reference point. In the case of annual crops, such extreme outcomes may be negative returns due to highly damaging climatic or sanitary events (frost, widespread pest attack..) causing an abnormally low production. The response of the crop and/or the frequency of the event, and thus the extent and the probability of the income loss, would be higher on marginal land than on plain land. Thus, we model cereal returns as a skewed-to-the-left distribution, the skewness being higher on marginal land (fat left-tail) than on plain land (thin left-tail). As far as perennial crops are concerned, extreme events may be extremely negative returns because of the large up-front costs. An establishment failure is not uncommon for perennial crops, and, in the case of energy crops, the risk of a failure from the contract counterparty raises some concern among farmers (Chapter 2 and Alexander et al. (2011)). The latter does not depend on land type. Hence, we assume that the distribution of perennial returns includes extremely negative values on both marginal and plain land.

Figure 4.5 represents roughly the hypothesized return distributions for perennials and cereals, as above discussed.



(a) Plain land



(b) Marginal land

Figure 4.5: Hypothesized distributions for returns from perennials and annuals according to land type

Effect of risk preferences on adoption

We now turn to the analysis of the theoretical impact of PT preferences on the optimal crop mix, given the return distributions of the crops, and thus on the adoption of the innovative perennial crop. The prospective value of a given crop mix depends on the ratio between the upside potential and the downside potential of the resulting return distribution (Equation (4.10b)), named hereafter *performance ratio*. On plain land, perennial returns are mostly in the loss domain, whereas cereal returns are mixed. On marginal land, perennial returns are mostly in the gain domain, whereas cereal returns are mixed. Thus, on plain land, if the farmer is neutral to risk, loss and probabilities, an increase of the share of perennials in the crop mix would lower the performance ratio. On the contrary, on marginal land, it would increase the performance ratio. Under PT, we need to consider each of the three PT parameters, namely the curvature of the value function, loss aversion a,d probability weighting. For each PT parameter, we first assume that the reference point is the mean cereal return, and then describe the changes that a modification of the reference point would imply.

Curvature of value function As mentioned in Section 4.2.1, PT value function is a piece-wise function, concave in the gain domain such as under expected utility, but convex in the loss domain. This last property implies a risk-seeking behavior over losses. In other words, when faced with all-loss prospects, subjects tend to prefer the riskier one because they get proportionally more pain from small losses than large losses.

Taking into account a non-linear value function does not change the negative direction of the impact of the share of perennial in the crop mix on the performance ratio on plain land. Indeed, the positive impact of a risk reduction on the upside potential would be outweighed by the negative impact of a risk reduction on the downside potential (perennial returns are mainly in the loss domain). As a result, the higher the curvature of the value function, the higher the diminution in the performance ratio, and the lower the optimal plain-land area planted with the perennial crop.

On marginal land, the crop distributions are symmetric relative to the plain-land distributions, thus an increase, in the curvature of the value function would have an opposite effect on the optimal perennial area, i.e., a positive effect.

In addition, by defining the domain of outcomes, the reference point has a major influence on the subsequent valuation of crop returns. For instance, a very high reference point on plain land would shift the cereal gains to the loss domain and move the perennial returns away from the reference point. Thus, the adoption of miscanthus would have no more risk-diversification effect in the gain domain, and the impact of an increase of the curvature of the value function would more negative than it was when the reference point was equal to the mean wheat return. On marginal land, a very high reference point could make the adoption of miscanthus have a negative effect on the performance ratio instead of a positive effect, and hence the curvature of the value function would be negatively linked with adoption, just as in the plain-land case.

Loss aversion PT also features loss aversion, which refers to the observed phenomenon that '*losses loom larger than gains*' (Kahneman and Tversky, 1984).[14] This asymmetry between gains and losses implies that the value of any asset with a distribution symmetrically distributed around the reference point would not be null. Rather, it would be negative because the downside potential would be higher than the upside potential.

Accounting for loss aversion does not change the negative direction of the impact of perennial crops on the performance ratio on plain land either. This is because, overall, gains are replaced by losses (perennial returns are quasi all-loss while cereal returns are mixed). As a consequence, the higher the loss aversion, the higher the decrease in the performance ratio, and the lower the optimal plain-land area of perennial crop.

On the contrary, in the symmetric marginal-land context, loss aversion would have a positive effect on the area of perennials.

The reference point also interacts with the way the adoption of a perennial crop impacts the performance ratio under loss aversion. If the reference point is so high that the two return distributions are all-loss, on plain land, the adoption of a perennial should still decrease the performance ratio under loss aversion (because the mean return is lower that that of the cereal), but at a lower rate (because no gains are replaced by losses). On the contrary, on marginal land,

14. Theoretically, loss aversion results from two properties: a higher curvature of the value function in the loss domain than in the gain domain and a linear coefficient applied to loss utilities. This 'global' loss aversion is sometimes called *behavioral loss aversion*. However, in most applications of PT, the parameter for curvature is the same in the gain and in the loss domain. Thus, behavioral loss aversion is only accounted for by the linear coefficient, and loss aversion refers indifferently to the behavior '*losses loom larger than gains*' or to the linear coefficient. '*The observed asymmetry between gains and losses is far too extreme to be explained by income effects or by decreasing risk aversion.*' (Kahneman and Tversky, 1984).

the adoption of a perennial should still decrease the performance ratio (because the mean return is higher that that of the cereal), but at a lower rate (because no losses are replaced by gains).

Probability weighting Under cumulative PT, the probability weighting function generally exhibits an inverse S-shape, implying the overweighting of extreme outcomes, especially if they are associated with small probabilities. It is as if the tails of probability distributions were fattened (and shortened), especially the very thin ones, to the detriment of the rest of the distribution.

Again, when accounting for probability distortion, perennials still have a negative impact on the performance ratio on plain land. As explained before, on this type of land, extreme events mainly characterize perennial crops. Thus, the higher the probability weighting, the higher the decrease in the performance ratio, and the lower the optimal plain-land area of perennial crop.

On marginal land, crop distributions relative to extreme events do not fundamentally change, even if the probability of extremely unfavorable events on cereals increases frankly. Thus, the influence of a higher probability distortion on perennial adoption would not be as negative as on plain land.

A change of the reference point does not modify the effect of probability weighting on the optimal area of perennials.

In conclusion, given farmers'preferences, perennials are expected to be an attractive option relative to cereals on marginal land mainly.

4.3.3 Hypotheses

The above analysis leads to the following set of hypotheses:

Hypothesis 1 *Factors reflecting resource constraints such as land and cash availability are expected to be important determinants of the adoption of perennials.*

Hypothesis 2 *Farmers' risk preferences are expected to matter in the adoption of perennials. Because the distribution of crop returns varies with the type of land, the impact of risk preferences is expected to vary if adoption occurs on plain land or on marginal land.*

Hypothesis 3 *More specifically, when the reference point is the mean return of the traditional crop, the curvature of the value function is argued to have a negative effect on adoption on plain land and a positive effect on marginal land.*

Hypothesis 4 *In addition, loss aversion is expected to have similar effects on adoption, i.e., a negative effect on adoption on plain land and a positive effect on marginal land.*

Hypothesis 5 *Moreover, probability weighting is expected to have a negative effect on adoption whatever the type of land. However, the effect should be stronger on plain land than on marginal land.*

Hypothesis 6 *A change in farmers' reference point is likely to modify the intensity of the effects of the value-function curvature and of loss aversion on adoption. The reference point may vary with farm history.*

Hypothesis 7 *Farmers' time preferences are expected to matter in the adoption of perennials, long-term discounting having a negative effect, and short-term discounting a positive effect .*

4.4 Data

4.4.1 Survey procedure

The study is based on a survey of miscanthus producers (adopters) and non-producers (non-adopters) from *Bourgogne*, in the east of France, and more especially *Côte d'Or* which is one of the administrative subdivision of *Bourgogne* (see Figure 4.6). In 2010, in *Côte d'Or*, 282 ha were planted with miscanthus or switchgrass and 351 ha in the whole *Bourgogne*), representing respectively 11% and 14% of the total French area (2,510 ha). Since 2009, most part of the *Côte d'Or* department and some part of the adjacent *Saône-et-Loire* and *Jura* departments are eligible to diversification incentives from a national program for the reorganization of the sugar supply chain (Programme de Restructuration National Sucre), following the reform of the EU sugar regime (Common Market Organization for sugar). Miscanthus and switchgrass production is one of the diversification activities which are supported. For farmers, main benefits are subsequent plantation subsidies (40% of the incurred costs as a minimum, with a cap at 70,000 €, which corresponds roughly to 22 ha).

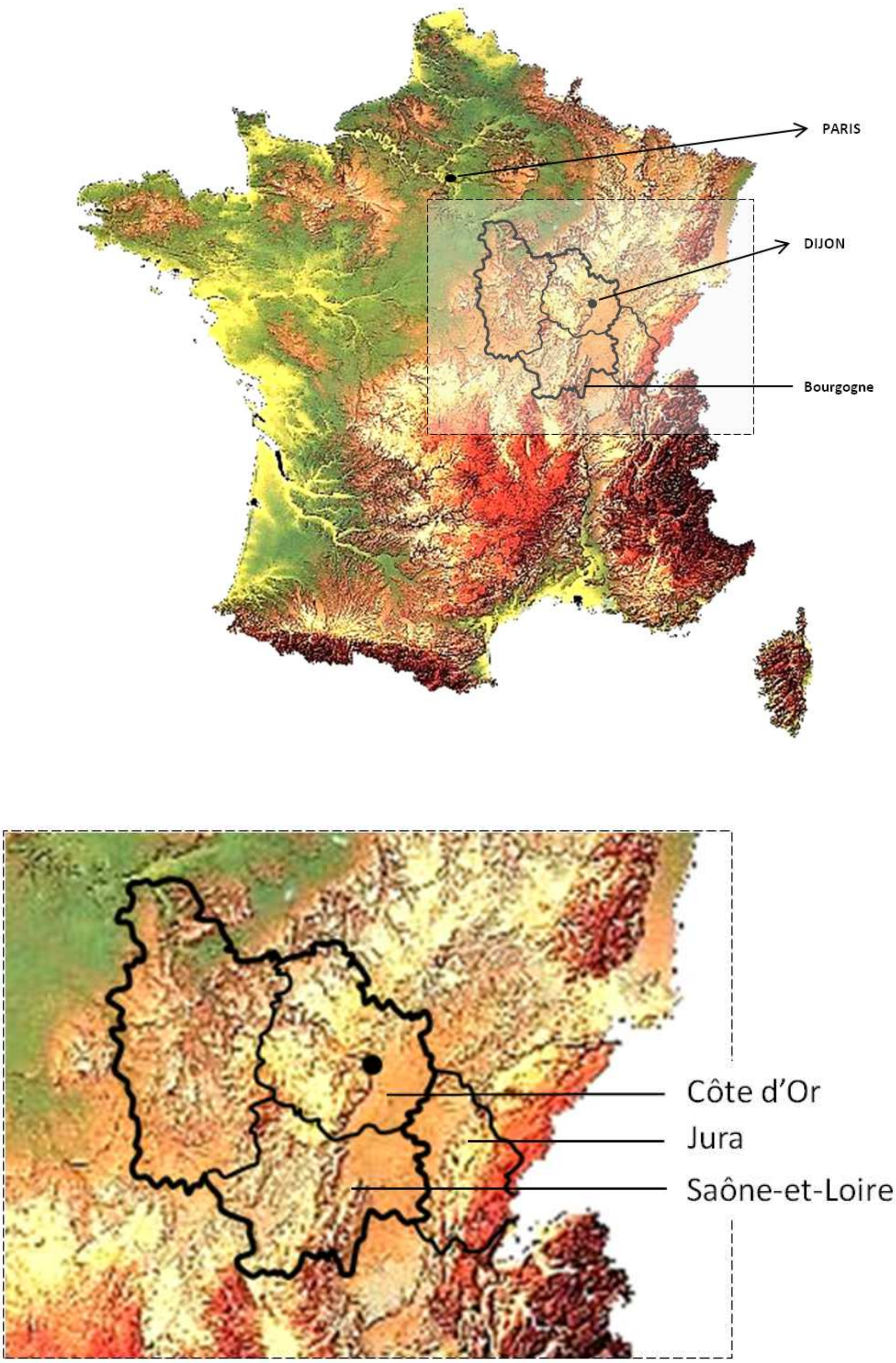


Figure 4.6: Location of *Bourgogne*

Being one of the most dynamic areas of miscanthus production in France, *Bourgogne* has the advantage of having a relatively high density of miscanthus producers. Indeed, collecting real adoption data about a very new crop for a quantitative analysis requires meeting a sufficient number of adopters. Besides logistic and budget issues, the choice of a single study area is justified by the avoidance of the selection bias due to incomplete information dissemination among potential adopters (see Section 4.5.1). Miscanthus being an innovation in an early diffusion stage, information diffusion is very heterogeneous and information bias is very likely. However, restricting the survey to one region has the drawback of reducing the heterogeneity in the pedo-climatic and economic environment. However, we limited the ensuing farm homogeneity by selecting a region which is diversified in terms of agricultural production. Main productions are cereals (soft wheat mainly) and oilseeds (rapeseed) on specialized farms, but livestock, market vegetables and wine are also important activities.

The population of interest consisted of the farmers living within the supply areas of two close processing plants located in *Aiserey* (south) and *Baigneux-les-Juifs* (north) (see Figure 4.7).[15] These plants are dehydration plants originally dedicated to the processing of lucerne and sugar-beet pulp respectively. Farmers from the *Aiserey* area are mainly located in the fertile plain of the *Saône* river, while most of the farmers from the *Baigneux-les-Juifs* area belong to the limestone plateau of *Bourgogne*. The climate is overall semi-continental, with long and harsh winters on the plateau. In the plain, cereals, oilseeds and proteincrops rotate with field vegetables (generally two vegetables per farm as a maximum).[16]

For adopters, complete address lists were available from the two dehydratation plants. Non-adopters were sampled from the list of farmers having received subsidies from the European Common Agricultural Policy in 2008. To further decrease potential information bias, we restricted the pool of farmers to those living in the towns featuring at least one miscanthus producer (592 farmers in 64 towns in total). Then, we built a stratified random sample from this initial pool of farmers, one strata encompassing all adopters, and the other stratum all non-adopters.[17] We deliberately over-represented adopters relative to non-adopters in order

15. Bourgogne Pellets (Aiserey, France) and Société Coopérative de Déshydratation de la Haute-Seine (Baigneux-les-Juifs, France)

16. Source: Agreste Bourgogne n°88, February 2008, available at: http://draaf.bourgogne.agriculture.gouv.fr/IMG/pdf/AgresteBourgogne88_leg_cle0e3251-1.pdf.

17. Because the stratification is based entirely on the binary response variable (Woolridge, 2010, p.854), the sample is called *choice-based*. Choice-based sampling belongs to the larger family of endogenous stratified sampling methods. Choice-based sampling is also related to intentional truncation: in choice-based samples

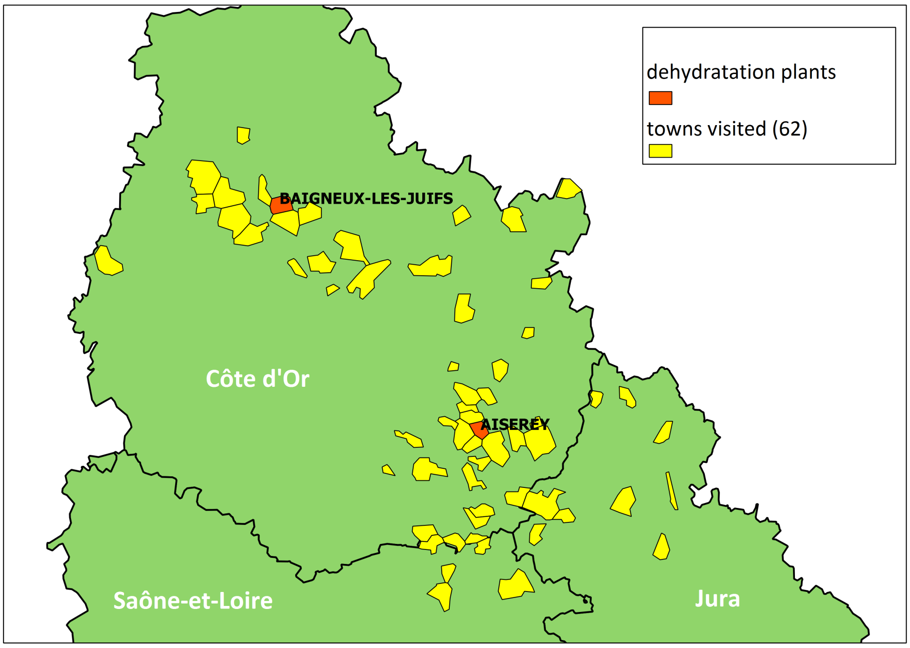


Figure 4.7: Location of the dehydratation plants and towns visited

to obtain a sample which is representative of the population of interest without expanding excessively the sample size. Indeed, even in *Bourgogne*, miscanthus growers are scarce relative to other farmers: adopters represent 16% of the initial pool.

We randomly picked up 80 adopters and 152 non-adopters from the initial pool of farmers. We first contacted them by mail, followed up by a phone call a few days later to make an appointment. The survey was presented as being about innovation in agriculture. In the end, 111 farmers could be surveyed within the allotted time, and 102 questionnaires were fully filled, corresponding to a response rate of 44% on average (excluding farmers who were not reachable, lacked time or did not show up). Compared to responses rates obtained in other adoption studies, it is rather high.[18] Finally, the sample consists of 57 adopters and 45 non-adopters, from 62 towns (see Figure 4.7).[19]

Despite the high response rate relative to other studies, the risk of sampling bias due

sampling frequencies can take different values depending on the response variable and in truncated samples sampling frequencies are either 1 (when the response falls in a given interval) or 0 (when it falls outside of the interval) (Woolridge, 2010, p.801).

18. For example, Jensen et al. (2007), Villamil et al. (2008) and Rämö et al. (2009), who investigated the interest in producing perennial energy crops among farmers or small private forest owners, reported response rates of respectively 24%, 21% and 41%. Mzoughi (2011) also highlights the difficulty of obtaining large response rates from French firms in his study about the role of moral and social concerns in farmers' adoption process: he obtained a response rate of 19% only.

19. In the sample, adopters represent 61% of the adopters from the whole population, and non-adopters represent 9% of the non-adopters from the whole population.

to non-response does exist. As we do not have any information about the characteristics of the population of interest, we can only control for this bias by comparing the characteristics of the sample with broader regional statistics. In Table 4.1, we provide statistics for the three departments of Bourgogne from which farmers were sampled. It can be seen from this table that the average farmer in the sample is consistent with an average *Côte d'Or* farmer regarding most characteristics (farm size, legal status, proportion of land owned, age). A major difference though is in the type of farm. In the sample, compared to *Côte d'Or* farms, fieldcrops farms are over-represented to the detriment of cattle farms and minor farm types. It is easily explained by the fact that the two processing plants are located in areas where farms are specialized in fieldcrops or mix fieldcrops with cattle. Thus, it cannot be an argument against the representativeness of the sample respect to the population of interest.

We organized face-to-face interviews from February to June 2010.[20] Each interview lasted around 2 hours. After the questionnaire was completed, farmers were invited to participate to a half-an-hour experiment aiming at measuring their preferences relative to risk, ambiguity and time. The design and the procedure of the experiment for the risk task are described in Chapter 3. The objectives of the questionnaire were twofold: identify the determinants of miscanthus adoption within the studied population and analyze miscanthus insertion in the actual production systems. In this paper, we report the results corresponding to the first objective only. The full questionnaire is included in Appendix F.[21] The questionnaire was built after direct interviews with local extension services and staff of the processing plants, and using insights from a previous survey in central France (Bocquého, 2008). The questionnaire was also pre-tested on farmers from another area.

20. Most of farm-level adoption studies rely on postal surveys, their main advantage being the collection of data from a large number of farmers at a low cost. However, compared to face-to-face surveys, there is little control over answer quality and the questionnaire needs to be kept short. In addition, with postal surveys, preferences measures necessarily rely on stated methods. Last, the response rate is usually much lower.

21. Most of questions are close-ended. Part 1 and 4 are dedicated to farmer and farm characteristics, including information about actual production systems and farm management. In part 3, farmers are asked to directly assess their objectives in farming, expectations about future economic conditions, and preferences. Part 2 is specific to miscanthus and differs between adopters and non-adopters. The former are asked (i) the agronomic and economic conditions in which they grow miscanthus, (ii) the reasons why they adopted miscanthus and why they do not grew it on a larger area, (iii) their perceptions about miscanthus attributes, and (iv) their willingness to extend the miscanthus area. Non-adopters are asked (i) the agronomic and economic conditions in which they would have grown miscanthus if they had adopted it, (ii) why they could have been interested in miscanthus and why they finally decided to not adopt it, and (iii) their perceptions about miscanthus attributes. In addition, farmers' willingness to adopt miscanthus under different contract conditions is assessed through stated methods.

Table 4.1: Characteristics of farmers in the sample, farmers from *Bourgogne* and French farmers in general

		Bourgogne			
	Sample[a,b]	Côte d'Or[c]	Saône-et-Loire[c]	Jura[c]	France[c,d]
Number of farms[e]	102	3,800	5,400	1,900	312,000
Average size of farms without vineyard[e]	169 ha	159 ha	117 ha	n.a.	94 ha
Legal status[e]					
sole proprietorship	38%	42%	60%	n.a.	55%
GAEC[f]	20%	12%	13%	n.a.	12%
EARL[f]	39%	32%	22%	n.a.	25%
other	3%	14%	5%	n.a.	8%
Farm type (specialist wine excluded)[e]					
specialist fieldcrops	74%	49%	8%	12%	27%
mixed crops–mixed livestock and mainly grazing livestock	22%	23%	11%	12%	15%
specialist cattle (rearing and fattening)	4%	16%	58%	6%	13%
other	<1%	12%	23%	71%	46%
Land owned on average	32%	31%	29%	n.a.	n.a.
Age of the farmer					
less than 40 years	15%	22%	23%	22%	19%
40 years and more	85%	78%	77%	79%	81%

[a] Weighted statistics.
[b] The repartition of the sampled farmers between the three departments of *Bourgogne* is as follows: 74% from *Côte d'Or*, 17% from *Jura*, and 9% from *Saône-et-Loire*. [c] Source: Agricultural census 2010, available at: http://www.agreste.agriculture.gouv.fr/recensement-agricole-2010/.
[d] Metropolitan France.
[e] Large and medium farms only. In *Côte d'Or* these farms represent 98,7% of the potential agricultural production and 97,5% of the agricultural surface area (Source: Agreste Bourgogne n°123, November 2011, available at: http://www.agreste.agriculture.gouv.fr/IMG/pdf_D2111A01.pdf. In fact, the unrepresented small farms encompass most of wine production and market gardening. [f] French legal statuses, GAEC standing for *Groupement Agricole d'Exploitation en Commun* (farming association) and EARL for *Exploitation Agricole à Responsabilité Limitée* (farmers' financial responsability is limited).

4.4.2 Descriptive statistics

A wide range of factors has already been identified as strongly influencing farmers' decision when facing the opportunity to grow a perennial energy crop. The choice of the explanatory variables included in our study was firstly guided by economic theory, previous empirical studies, and our own knowledge of the *Bourgogne* setting. A large number of variables was tested, but we selected the ones which gave to the estimated models the best trade-off between goodness-of-fit and parsimony Table 4.2 describes the variables used in the models and Table 4.3 provides statistics for the entire sample and the two sub-samples of non-adopters and adopters.

Dependent variables Participation to miscanthus production whatever the land type, participation on plain land, and participation on marginal land are represented by the binary variables *Adopter*, *PlainUsed*, and *MarginUsed* respectively. They take on the value 1 if the farmer had planted miscanthus at least once on the given land type at the time he or she was interviewed. On average, the probability of overall adoption is 18%, the probability of adoption on plain land 9%, and the probability of adoption on marginal land is 11%. These probabilities partly reflect the strong incentive that plantation subsidies represent by, at the same time, reducing up-front costs and increasing long-term profitability. Both have been repeatedly cited as important barriers to the adoption of perennial energy crops.

Adoption intensity (*MiscAcreage*) is measured as the cumulative acreage allocated to miscanthus in 2010.[22] On average, adopters grow about 4.6 ha of miscanthus, representing 2.6% of the average farmland. Among adopters, 49% allocated only marginal land to miscanthus, 35% only plain land and 16% only chose a mixed allocation. Thus, marginal land seems to be preferred to plain land to grow miscanthus.

Marginal land is land that farmers stated to match the following definition: '*Do you think some of your land is particularly difficult to farm relative to the rest of your land, due to high costs (included labor costs), low yields, or other constraints?*'. In other words, it is a land that is less profitable than the rest of the land of the farm. It is a subjective and relative definition because we were interested in the allocation decision, which is also subjective (depends on farmers' preferences and perceptions) and relative (is made at the farm-level). The question was

22. The proportion of land allocated to miscanthus out of the total farmland was also tested as a dependent variable. However, the fit of the models was lower. From an economical point of view, using absolute surface areas is not problematic because the land constraint is far to be binding.

Table 4.2: Variable description

Dependent variables	
Adopter	1=grows miscanthus; 0 otherwise
MiscAcreage	total acreage allocated to miscanthus (ha)
PlainUsed	1=grows miscanthus on plain land at least partly; 0=otherwise
MarginUsed	1=grows miscanthus on marginal land at least partly; 0=otherwise
Explanatory variables	
Farmer characteristics	
Age	age of the farmer (years)
ExtraInc	proportion of the household income coming from another professional activity than farming
PublicInfo[a]	importance of public extension services and media as a source of information
PrivateInfo[a]	importance of private extension services as a source of information
Farm characteristics	
FarmSize	total arable area (100 ha)
LandOwned	proportion of land out of the arable area which is owned
Livestock	1=has livestock; 0 otherwise
ExBeet	1=former beet producer; 0 otherwise
Margin	1=has some marginal land on the farm; 0=otherwise
IdleLand	proportion of idle land out of the arable area in 2009
PlotSize	average plot size (ha)
Wood	1=owns woods; 0 otherwise
North	1=farm located in the northern part of the study area; 0 otherwise
WheatRisk[b]	importance of risk faced on soft wheat (1-5 score)
Individual preferences	
EnvironObjFirst[c]	1=reaching good environmental performances is the first objective; 0 otherwise
VConcavity	PT parameter for concavity of the utility function in the gain domain
LossAversion	PT parameter for loss aversion
WeightExtreme	PT parameter for the weight given to extreme events
StdDiscount	HD parameter for the standard discount factor
PresentBias	HD parameter for the present bias factor

[a] The variables *PublicInfo* and *PrivateInfo* are the coordinates on the first and the second components of a principal component analysis (PCA). In the PCA, we included 9 Likert-type items rating farmers' sources of technical information (1=not important at all, 5=very important): farming magazines, neighbours, bulletin from the Chamber of Agriculture, technicians from the Chamber of agriculture, bulletin from the business partners, technician from the business partners, professional fairs and exhibitions, conferences and specific training sessions, internet.
[b] The variable *WheatRisk* is the mean score of several Likert-type items measuring farmers' perception of wheat production exposure to several types of risks (1=not important at all, 5=very important): blight risk, pest risk, climate risk, weed risk, management risk, location risk, price risk, outlet risk, cost risk, environmental regulation risk. [c] The variable *EnvironObjFirst* is set to 1 if farmers chose as their first objective in farming among a list of 18 potential objectives.

Table 4.3: Weighted descriptive statistics

	Full sample		Non-adopters		Adopters	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Dependent variables						
Adopter	0.18	0.38	0.00	0.00	1.00	0.00
MiscAcreage	0.81	2.82	0.00	0.00	4.60	5.29
PlainUsed	0.09	0.29	0.00	0.00	0.51	0.50
MarginUsed	0.11	0.32	0.00	0.00	0.65	0.48
Explanatory variables						
Farmer characteristics						
Age	47.68	8.85	48.53	8.55	43.67	9.39
ExtraInc	0.26	0.25	0.25	0.26	0.31	0.23
PublicInfo	−0.09	1.59	−0.22	1.56	0.49	1.63
PrivateInfo	−0.03	1.44	−0.04	1.48	−0.00	1.28
Farm characteristics						
FarmSize	1.69	0.96	1.56	0.90	2.28	1.03
LandOwned	0.32	0.21	0.33	0.21	0.28	0.22
Livestock	0.24	0.43	0.24	0.43	0.23	0.42
ExBeet	0.34	0.48	0.31	0.47	0.49	0.50
Margin	0.80	0.40	0.78	0.42	0.93	0.26
IdleLand	0.03	0.03	0.03	0.03	0.04	0.04
PlotSize	6.67	3.73	6.41	3.36	7.86	5.03
Wood	0.35	0.48	0.36	0.48	0.32	0.47
North	0.24	0.43	0.24	0.43	0.25	0.43
WheatRisk	3.33	0.57	3.32	0.56	3.39	0.64
Individual preferences						
EnvironObjFirst	0.03	0.18	0.02	0.15	0.09	0.29
VConcavity	0.50	0.43	0.51	0.45	0.44	0.37
LossAversion	3.86	3.35	3.97	3.52	3.34	2.45
WeightExtreme	0.38	0.33	0.40	0.34	0.31	0.31
StdDiscount	0.88	0.07	0.87	0.07	0.89	0.07
PresentBias	1.11	0.09	1.11	0.09	1.07	0.10
Nb. of observations	102		45		57	

asked at the very beginning of the questionnaire in order to avoid interferences with questions about miscanthus. In the end, land indicated as marginal mostly corresponds to poor soil conditions (64% of the total area declared as marginal): low fertility, hydromorphy or dryness, presence of stones.

Explanatory variables Explanatory variables can be divided into three groups: farmer characteristics (socio-demographics and economics), farm characteristics (resources, economic and geographical context), and farmers' preferences. On average, the interviewed farmers are 48 years old. Farming is the main income source for the households, but, on average, 26% comes from another professional activity than farming. The mean farm size is 169 ha, with 32% of the farm land being owned by the farmer. Farmers breeding livestock represent 24% of the sample, and those being beet producers before the reform of the EU sugar regime 34%. On average, 80% of the sampled farmers have marginal land, and idle land represents 3% of the farm land.

The dummy variable *North* distinguishes farmers from *Baigneux-les-Juifs* area (*North*=1, 24% of the sample)) from those from *Aiserey* area. As mentioned before, pedo-climatic conditions are less favorable in the north than in the south. Contract conditions are slightly less advantageous as well. However, the economic conditions surrounding miscanthus adoption are roughly homogeneous over both sub-areas. Indeed, the two dehydration plants are the only outlet for miscanthus, and they both offer incentive production contracts to farmers: all contracts guarantee a long-term outlet for the crop, at a minimum price (see Chapter 2), which is the main concern for farmers on an emerging market (see Chapter 1 and Alexander et al. (2011)). The policy conditions are also the same over the whole area under study: nearly all adopters (50 out of 57) benefited from plantation subsidies from the regional diversification plan launched in 2009. In fact, most miscanthus was planted for the first time in 2009 (22 adopters out of 57) and 2010 (23 adopters out of 57).

In this study, particular attention is paid to farmers' risk and time preferences. As already mentioned, they were elicited experimentally for each farmer in the sample under PT and HD respectively. Some assumptions on their functional form were needed to estimate relevant parameter values in the experiment.[23] Regarding PT preferences, we used common functional

23. The method used for the estimation is a common one in experimental studies. It consists in calculating bounds for the parameters from the observed lottery choices. The mid-point of the elicited intervals gives the parameter value.

forms which led to measures for three parameters, each one describing curvature of the value function, loss aversion or probability weighting. Each parameter was then used as an explanatory variable for miscanthus adoption. The variables for the curvature of the value function (*VConcavity*) and loss aversion (*LossAversion*) correspond to the parameters σ and λ of a power value function defined separately over gains and losses (Tversky and Kahneman, 1992):

$$u(y) = \begin{cases} y^{\sigma} & \text{if } y > 0 \\ 0 & \text{if } y = 0 \\ -\lambda(-y)^{1-\sigma} & \text{if } y < 0. \end{cases} \tag{4.11}$$

In this specification, σ is an index of concavity in the gain domain (and convexity in the loss domain) [24], [25] and λ is the coefficient of loss aversion. On average, in the sample, *VConcavity*>0 and *LossAversion*>1 , meaning that farmers exhibit the usual PT behavior, namely risk aversion in the gain domain (and risk seeking in the loss domain) and loss aversion. The higher *VConcavity*, the stronger the risk aversion in the gain domain (and the risk seeking in the loss domain), and the higher *LossAversion*, the higher the aversion to loss relative to gains.

As for probability weighting, it is measured by *WeightExtreme* which corresponds to the parameter γ in the following function (Prelec, 1998):

$$\omega(p) = \exp\left[-(-\ln p)^{(1-\gamma)}\right]. \tag{4.12}$$

The parameter γ controls the curvature of the weighting function. If $\gamma > 0$, the weighting function has an 'inverse S-shape', whereas if $\gamma < 0$ the function takes the less conventional 'S-shape'. [26] Once again, in the sample, farmers behave in accordance with the usual empirical finding: *WeightExtreme* is on average positive, meaning that farmers tend to more sensitive to changes in ranks close to the extreme values 0 and 1. In practical terms, the higher *WeightExtreme*, the more farmers focus on extreme outcomes.

24. In PT, risk attitude depends on other factors besides the curvature of the value function, namely loss aversion and probability weighting. Thus, σ is no longer an index of risk attitude but just a measure of the curvature of the value function.

25. In Chapter 3, which describes the results of the experiment, σ is an index of *convexity*. In this chapter, for the ease of interpretation, we use an index of *concavity*. The relationship between both is $\sigma_{\text{Chapter 3}} = 1 - \sigma_{\text{Chapter 4}}$.

26. Once again, to facilitate interpretation, we replace the weighting parameter γ of Chapter 3 by $1 - \gamma$. Whereas in Chapter 3 γ is an index of likelihood sensitivity, and $\gamma < 1$ characterizes an inverse S-shape, in this chapter, it is an index of likelihood *insensitivity*.

In the experiment, we did not explicitly measure farmers' reference point, but assumed it was zero. Thus, we cannot explicitly control for the impact of farmers' reference point on adoption. However, *ExBeet* may be correlated to a high reference point because before the reform of the EU sugar regime, beet was a crop providing a quite high and stable income. As a consequence, former beet producers may have a higher reference point than other farmers.

Regarding HD preferences, we used a quasi-hyperbolic specification. The quasi-hyperbolic discount structure captures the essence of hyperbolic discounting while keeping the analytical tractability of exponential discounting (Phelps and Pollak, 1968; Laibson, 1997; O'Donoghue and Rabin, 1999) [27]. It is described by two parameters δ and β, matching respectively the variables *StdDiscount* and *PresentBias*:

$$D(t_i) = \begin{cases} 1 & \text{if } t_i = 0 \\ \beta.\delta^{t_i} & \text{if } t_i > 0, \qquad \beta, \delta \in]0;1] \end{cases} \tag{4.13}$$

In this expression, δ is the standard discount factor, representing long-run, time-consistent discounting, and β is the present-bias factor, capturing short-term impatience. The standard exponential discounting model is nested as a special case of quasi-hyperbolic preferences when $\beta = 1$. On average, in the sample, *PresentBias*<1, meaning that farmers do discount events in the near future at a higher discount rate than events in the distant future. From a practical perspective, the higher *StdDiscount*, the *lower* the long-term discounting, and the higher *PresentBias*, the *lower* the short-term discounting and the immediacy effect.

4.5 Econometric methods

There are three variables of interest. The first one is the total amount of land farmers decided to allocate to miscanthus. As it is often the case with data about the adoption of a divisible technology, this variable yields many zero responses, and outside of the zero focal point, is is continuously distributed. The two other variables are dummies corresponding to farmers' decision to grow miscanthus on plain land. They also yield many zero responses.

Several econometric models are technically available to deal with such non-negative or

27. Formally, Loewenstein and Prelec (1992) proposed the following functional form for real hyperbolic discounting: $D(t_i) = (1 + \alpha t_i)^{\beta/\alpha}$, $\alpha, \beta > 0$.

binary variables and avoid biased estimates, but the choice of one model or another should be derived from the economic model of Section 4.3. Let us first examine the ways in which zero responses can arise, check their adequacy to our specific problem, and then propose the suitable econometric specifications.

4.5.1 Origin of zero responses

At least three phenomena can be invoked to explain the process generating zero responses.

Data collection

Zero responses can simply arise from the technical constraints of the collection method for the data. For instance, in consumption studies, observation periods are short and it is highly probable that individuals may not purchase a particular good within the allocated time for the expenditure survey, despite their regular consumption of the good (Pudney, 1989). *Censoring* of the dependent variable is another very general problem in microeconomics. Values in a certain range may be all reported as a single value, e.g., all incomes below a certain threshold (Greene, 2008).

In our survey procedure, there is no data-collection issue. First, miscanthus plantations are all grouped in late winter and we conducted our field survey from February onwards. Thus, at that moment, all the adoption decisions for the current year had been taken and materialized by either an effective plantation or a formal commitment with miscanthus processors. In addition, miscanthus adoption is a long-term decision: the acreages declared at the time of the survey did encompass all plantations from the previous years. Second, as we collected the exact surface areas, there is no censoring of the variable of interest.

Selection

Another possible explanation for zero responses is the existence of a specific 'regime' under which the variable of interest is constrained or cannot be observed for some part of the population. If the researcher intends to draw conclusions only for the unconstrained or observed regime, the observations are said to be *selected* (or *truncated*). The best-known selection situation is *sample selection*, when some individuals of the full population are not included in the sample due to the sampling procedure. In that particular case, some observations are missing. In more general cases of selection, the explanatory variables are fully observed but the variable of interest is unobservable for some individuals (e.g., women wages can be observed only for women who do work) (Greene, 2008), or does not reflect a real choice because barriers prevent subjects to do what they want (e.g., product shortage, lack of information about the options) (Pudney, 1989).[28] In both cases, if the selection process is based on an endogeneous citerion, estimates will be most probably biased (selection bias[29]). Indeed, if the selection criterion is correlated with the variable of interest, variations in the relationship between the dependent variable and the explanatory variables will not be random and will not be able to be absorbed into stochastic disturbance terms.[30]

In this study, as detailed in Section 4.4.1, the interviewees were selected basing on a stratified random-sampling procedure. Thus, our estimates are not expected to suffer from sampling bias.[31]

However, another potential source of selection bias is worth examining. Indeed, the extent of miscanthus adoption may be conditioned by farmers' access to information. Because miscanthus is in an early development phase, all farmers might not be aware of this opportunity. For these farmers, zero-responses reflect a lack of information rather than a real decision of not adopting miscanthus. Nevertheless, by limiting our survey to an area that is small and dynamic in terms of miscanthus promotion, we ensured that all the farmers in the sample had an equal access to the adoption option and hence the information bias was minimized (see Section 4.4.1).

Last, the third variable of interest, i.e., adoption on marginal land, is obviously constrained by the existence of some marginal land on their farm. Thus, if the selection criterion 'having some marginal land on the farm' is correlated with the variable of interest 'allocating some marginal land to miscanthus', estimating the parameters of adoption decision on marginal

28. In the literature, *sample selection* is often used indifferently to designate both selection situations, namely unobserved outcome because of missing individuals (real sample selection) or unobserved outcomes due to subjects' particular situation. We prefer to reserve the *sample selection* qualifier to the first case, as a special case of more general selection issues.

29. Following our terminology, we will restrict the use of the term *sampling bias* to real sample-selection problems.

30. One of the remedies to selection bias is to control for all the factors involved in the selection mechanism. In the case of information bias, it is difficult to measure precisely the quantity and quality of information received by farmers when they took the adoption (or non adoption) decision. Another option is the use of selection models of the Heckman type. Saha et al. (1994) implemented this type of model to correct specifically for information bias, in the context of the adoption of a growth hormone by dairy producers.

31. A stratified sample may yield estimates that are less subject to sampling error than estimates derived from a random sample of equal size.

land only from the unconstrained observations (those farmers who do have some marginal land on their farm) may be flawed by selection bias. In other words, deleting the farmers who do not have marginal land from the sample may be problematic only if the selection criterion is endogenous. The question is: are there some unobservable characteristics affecting the adoption decision which are correlated with those affecting the presence of marginal land on the farm? Put another way: is the reason why farmers have some marginal land random respective to the adoption decision? The answer to the last question is yes, probably. Thus, we do not expect the non-existence of marginal land on the farm to be an important source of bias.

Corner solution

Data-collection and selection issues have in common the fact that zero responses are an observational artifice. Nevertheless, zero responses can also be *true* zeros, i.e., the expression of a completely free choice. In this case, they correspond to corner solutions of subjects' optimization problem: given the available choice options and subjects' own preferences, subjects may not have any economic in purchasing or producing a good.

From Equation (4.10a), because the amount of land allocated to crops cannot be negative, we infer that, if the new crop is viewed as less valuable the traditional one, the amount of land allocated to the new crops will be null.

4.5.2 Econometric models

In the previous section, we discussed the origins of the zero observations in our variables of interest. We showed that they were constrained observations generating no bias or corner solutions. We now derive the suitable econometric specifications for our adoption problem.

Most often, in the literature on technology adoption, the corner solution issue is managed with the standard tobit model when the amount of land converted is available (e.g., Adesina and Baiduforson, 1995; Abadi Ghadim et al., 2005; Jensen et al., 2007; Roos et al., 2000). However, applying the tobit modeling procedure lays the assumption that the equation determining whether an observation is at the zero limit is the same as the equation explaining the positive values.[32]This property conflicts with the fact that there may be two decisions at work in

32. Tobit models are adequate for real censored data, when observations are piled up at a limiting value for technical reasons (related to data collection), but '*has no foundation in behavioral theory*' (Pudney, 1989). As

adoption models, first whether to adopt the technology or not, and second to what extent adopt it. Two-equation extensions of tobit models do allow different mechanisms for the *participation* and *intensity* decisions. In these models, the first equation corresponds to a binary variable (participation equation) and the second equation to a positive variable *conditional* on having adopted in the first phase (intensity equation).

Two-part models are particular two-equation extensions of tobit mdoels which have been widely used in consumption studies and health economics (Jones, 1989, 2000; Ground and Koch, 2008), or finance (Moffatt, 2005).[33] They have recently entered the field of agricultural and environmental economics (Martínez-Espiñeira, 2006; Bekele and Mekonnen, 2010; Mishra, 2009), including to explain technology adoption (Kassie et al., 2009; Teklewold et al., 2006; Smith et al., 2011).[34]

Adoption whatever the land type

We analyze the determinants of miscanthus adoption whatever the land type by estimating, first, the usual tobit model, and then, a linear two-part model. The intensity variable, i.e., the total amount of land allocated to miscanthus by farmer i, is denoted by y_i. It is a positive continuous variable with a mass point at 0 because for some agents the optimal decision is the corner solution $y_i = 0$. Let X_i be a vector of all observable explanatory variables (farmer and farm characteristics, farmers' individual preferences).

Standard tobit[35]

highlighted by Greene (2008), they predict '*not only a cluster of zeros (or limit observations), but also a grouping of observations* near zero *(or the limit point)*'.

33. Other alternatives for corner solution responses include double-hurdle models (Blundell and Meghir, 1987; Jones, 1989, 1992), log-normal hurdle models (Woolridge, 2010), and exponential type II tobit models (Woolridge, 2010). Double-hurdle models assume that two hurdles must be crossed before zero values are observed, one of the hurdle being generally motivated by non economic factors. Log-normal hurdle models are a log-linear variant of two-part models. Exponential type II tobit models are a generalization of two-part models when the participation and intensity decisions are assumed to be correlated.

34. In fact, Martínez-Espiñeira (2006), Bekele and Mekonnen (2010), Mishra (2009) and Teklewold et al. (2006) describe a double-hurdle model in their paper, but use the separability of the log-likelihood into a probit and a truncated regression to estimate the parameters of the model, which is characteristic of a two-part model.

35. The standard tobit model corresponds to Amemiya's (1984) type I tobit model. The qualifier *censored regression model* is also very common, and highlights the fact that the tobit model should be reserved for real censored data issues, as opposed to corner solution responses.

The tobit specification for the (unconditional) intensity variable is:

$$y_i^* = \beta X_i + \varepsilon_i, \qquad y_i = \begin{cases} y_i^* & \text{if } y_i^* > 0 \\ 0 & \text{otherwise} \end{cases} \tag{4.14}$$

where β is the vector of parameters to be estimated, ε_i are independent and identically distributed (i.i.d.) stochastic error terms capturing unobserved heterogeneity in behavior (all unobservable factors having an effect on the variable of interest), and $\varepsilon_i|X_i \sim N(0, \sigma^2)$.

The parameters of the standard tobit model are estimated by maximum likelihood. If the sample observations are divided into those being zero and those being positive, the log-likelihood function is:

$$\ln L(y_i; \beta) = \sum_{i|y_i=0} \ln[1 - \Phi(\beta X_i/\sigma)] + \sum_{i|y_i>0} \ln\left[\frac{1}{\sigma}\phi\left(\frac{y_i - \beta X_i}{\sigma}\right)\right] \tag{4.15}$$

where $\Phi(.)$ is the standard normal cumulative distribution function.

Two-part model[36]

In a two-part model, the participation decision and the (conditional) intensity decision are generated by distinct underlying processes (Cragg, 1971):

participation equation:

$$z_i^* = \gamma X_i + \nu_i, \tag{4.16}$$

intensity equation for non-zero responses:

$$y_i^* = \beta X_i + \varepsilon_i, \qquad y_i = \begin{cases} y_i^* & \text{if } z_i^* > 0 \\ 0 & \text{otherwise} \end{cases} \tag{4.17}$$

where β and γ are vector of parameters to be estimated, ν_i and ε_i are random error terms,

36. Woolridge (2010) uses the qualifier *truncated normal hurdle model.*

and $\nu_i|X_i \sim N(0,\delta^2)$. The distribution of $\varepsilon_i|X_i$ is truncated normal with lower truncation point $-\beta X_i$, based on an non-truncated normal distribution $N(0,\sigma^2)$(Woolridge, 2010). The truncation ensures that y_i^* is non-negative. The justification is that the value of the variable of interest y_i depends on the regime under which the variable is observed: it is a zero value if the participation condition is met and a positive value if it is not. [37]

Following the usual Cragg's (1971) version of this model, we assume that ν_i and ε_i are independent conditional on the set of observed covariates. The log-likelihood of the independent two-part model is:

$$\ln L(y_i;\beta,\gamma) = \sum_{i|y_i=0} \ln\left[1-\Phi(\gamma X_i)\right] + \sum_{i|y_i>0} \ln\left[\frac{1}{\sigma}\phi\left(\frac{y_i-\beta X_i}{\sigma}\right) \cdot \frac{\Phi(\gamma X_i)}{\Phi\frac{\beta X_i}{\sigma}}\right]. \quad (4.18)$$

The term $\frac{1}{\Phi\frac{\beta X_i}{\sigma}}$ ensures that the density integrates to unity over $y_i > 0$ (truncated distribution).

From Equation (4.18), it is straightforward that the log-likelihood can be written as the sum of the log-likelihoods of a probit model and a truncated-at-zero regression model (Mc Dowell, 2003; Woolridge, 2010). Hence, the parameter vectors γ and β are estimated separately, γ with the Stata command *probit* applied to the full sample, and β_2 with the command *truncreg* applied to the $y_i > 0$ observations (the direct Stata command *craggit* is another possible option). The two-part model reduces to the standard tobit model when $\gamma = \beta/\sigma$ (and regressors are the same in the participation and the intensity equation).

Adoption according to the type of land

The participation variable on plain land is denoted by y_i and the participation variable on marginal land is denoted by z_i. They are binary variables taking on the value 1 if the farmer i grows miscanthus on the given land type and 0 otherwise. We assume that the two decisions are taken jointly, and thus that some unobserved factors may influence both decisions. As outlined in Section 4.5.1, zero responses from farmers having no marginal land are constrained observations, but they are not expected to generate any bias.

37. The truncated distribution of y_i^* is the fundamental technical difference with Heckman selection models (or Tobit type II). Indeed, selection models are theoretically relevant to model selection issues with zeros being unobserved values. In these models, the observed responses are not restricted to positive values, and thus are density consistent.

We deal with this joint decision by estimating a *bivariate probit model.* Once again, let X_i be a vector of all observable explanatory variables (farmer and farm characteristics, farmers' individual preferences). The bivariate probit is written:

participation equation for plain land:

$$y_i^* = \beta X_i + \varepsilon_i, \qquad y_i = \begin{cases} 1 & \text{if } y_i^* > 0 \\ 0 & \text{otherwise} \end{cases} \tag{4.19}$$

participation equation for marginal land:

$$z_i^* = \gamma X_i + \nu_i, \qquad z_i = \begin{cases} 1 & \text{if } z_i^* > 0 \\ 0 & \text{otherwise} \end{cases} \tag{4.20}$$

where β and γ are vector of parameters to be estimated and ν_i, ε_i are random error terms. The error terms are correlated and assumed to have a bivariate normal distribution such that : $\begin{pmatrix} \nu_i \\ \varepsilon_i \end{pmatrix} \sim N(0, \Sigma)$, with $\Sigma = \begin{pmatrix} 1 & \sigma\rho \\ \sigma\rho & \sigma^2 \end{pmatrix}$, ρ being the correlation coefficient. The dummies coding for the two participation variables are the expression of two latent variables y^* and z^* : the amount of plain land and the amount of marginal land allocated to miscanthus. The correspondence is such that 0 codes for no allocation and 1 for any positive amount of land. We estimate the bivariate probit by maximum likelihood with the Stata command *biprobit.*

To account for our stratified survey design, we used for all estimations the *svy:* prefix which computes corrected point estimates and standard errors.[38] All the estimations were performed with Stata 11.2 software.

38. In order to use the information about weights *and* stratification, and get smaller standard errors, we prefer to use the Stata *svy:* option rather than the simple *pweight* option. With both options, the estimations rely on the maximization of weighted log-likelihoods: for each farmer, the weight is equal to the inverse of the probability that the farmer would be selected.

4.6 Results and discussion

For each of the models explaining miscanthus adoption, we estimate by maximum likelihood the linear coefficients and the average marginal effects of the explanatory variables. To assess the goodness-of-fit of the models, we mainly base on their predictive power, i.e., the proportion of observations correctly predicted (for binary outcomes) and the proportion of variance explained (for continuous outcomes).[39]

4.6.1 Adoption whatever the land type

In this section, we analyze the factors influencing adoption whatever the type of land, through a tobit model and several two-part models for which we vary the set of regressors.

Full set of regressors

Estimates of the linear coefficients of the base tobit and two-part models (models T and A0 respectively) are displayed in Table 4.4, and estimates of the corresponding marginal effects in Table 4.5.

As it can be seen in the lower part of Table 4.4, models T and A0 predict the participation decision with the same accuracy (85% and 87% of the observations correctly predicted respectively). However, the two-part model A0 is much more reliable in explaining the variance in the intensity decision: 42% of the variance of the observations is explained against 11% for the tobit model. This means that it is worth disentangling the participation and intensity decisions to study miscanthus adoption. Using one model or the other is not without consequence. Indeed, the two models lead to different estimates, including estimates with opposite signs (see *Livestock* and *Margin* for instance). In the rest of the paper, we will focus on the results from the most accurate specification, namely the two-part specification.

Participation decision Column 3 of Table 4.5 presents the estimated marginal effects for the participation equation of the two-part model, i.e., farmers' decision about whether to allocate land to miscanthus.

39. Because we use survey data and calculate pseudo log-likelihoods instead of log-likelihoods, the usual selection criteria such as the likelihood-ratio test, Akaike's (1973) information criterion or Schwarz's (1978) Bayesian information criterion give flawed indications (Source: Stata FAQs - updated September 2005, available at: http://www.stata.com/support/faqs/stat/lrtest.html).

Table 4.4: Models of miscanthus adoption

	Model T (tobit model)		Model A0 (two-part model)			
	Intensity (MiscAcreage)		Participation (Adopter)		Intensity (MiscAcreage)	
	Coeff.	Std. Err.	Coeff.	Std. Err.	Coeff.	Std. Err.
Constant	49.927	(37.981)	4.621	(5.594)	37.500**	(18.183)
Farmer characteristics						
Age	−0.194	(0.118)	−0.030	(0.019)	−0.028	(0.059)
ExtraInc	10.035*	(5.418)	1.092	(0.683)	2.694	(3.406)
PublicInfo	0.672	(0.640)	0.085	(0.096)	0.474	(0.428)
PrivateInfo	−0.198	(0.691)	−0.039	(0.103)	0.100	(0.390)
Farm characteristics						
FarmSize	3.180***	(1.191)	0.520***	(0.181)	0.453	(0.814)
LandOwned	−6.808	(6.154)	−0.975	(0.865)	−1.454	(3.668)
1.Livestock	−2.934	(2.575)	−0.669	(0.404)	1.717	(1.666)
1.ExBeet	3.209	(2.488)	0.552	(0.362)	−1.696	(1.834)
1.Margin	4.279	(3.324)	0.764	(0.462)	−5.700	(3.575)
1.Wood	4.618*	(2.490)	0.495	(0.349)	2.362	(1.609)
1.North	−1.994	(2.575)	−0.093	(0.379)	−4.483*	(2.298)
WheatRisk	0.415	(1.858)	0.083	(0.271)	0.167	(0.995)
Individual preferences						
1.EnvironObjFirst	2.913	(3.200)	0.935	(0.657)	−0.969	(1.723)
VConcavity	2.488	(2.602)	0.223	(0.360)	1.086	(1.458)
LossAversion	0.122	(0.357)	0.014	(0.054)	0.194	(0.244)
WeightExtreme	−6.329*	(3.452)	−0.920**	(0.429)	−4.116	(3.293)
StdDiscount	−37.368	(25.391)	−3.282	(3.885)	−28.508**	(11.715)
PresentBias	−26.379	(19.457)	−2.996	(2.545)	−2.177	(9.293)
σ	8.131***	(1.426)			4.207***	(0.563)
Nb. of observations	102		102		57	
Model p-value	0.01		0.05		0.81	
Proportion correctly predicted	0.85		0.87			
Proportion variance explained	0.11				0.42	

*, ** and *** stand for significance at the 10, 5 and 1% level, respectively. The standard errors are adjusted for our survey design.

Table 4.5: Marginal effects on miscanthus adoption

	Model T (tobit model)		Model A0 (two-part model)			
	E(MiscAcreage)		Pr(Adopter=1)		E(MiscAcreage|Adopter=1)	
Farmer characteristics						
Age	−0.032	(0.019)	−0.006	(0.004)	−0.018	(0.038)
ExtraInc	1.638*	(0.881)	0.208	(0.127)	1.734	(2.186)
PublicInfo	0.110	(0.105)	0.016	(0.018)	0.305	(0.275)
PrivateInfo	−0.032	(0.113)	−0.007	(0.020)	0.064	(0.251)
Farm characteristics						
FarmSize	0.519***	(0.192)	0.099***	(0.030)	0.292	(0.524)
LandOwned	−1.111	(1.010)	−0.186	(0.165)	−0.936	(2.362)
1.Livestock	−0.433	(0.349)	−0.107*	(0.055)	1.157	(1.171)
1.ExBeet	0.555	(0.462)	0.112	(0.077)	−1.094	(1.179)
1.Margin	0.566	(0.352)	0.122**	(0.059)	−4.445	(3.194)
1.Wood	0.861	(0.530)	0.098	(0.072)	1.588	(1.125)
1.North	−0.299	(0.358)	−0.017	(0.070)	−2.585**	(1.190)
WheatRisk	0.068	(0.303)	0.016	(0.052)	0.108	(0.640)
Individual preferences						
1.EnvironObjFirst	0.581	(0.759)	0.229	(0.191)	−0.601	(1.029)
VConcavity	0.406	(0.425)	0.043	(0.068)	0.699	(0.940)
LossAversion	0.020	(0.058)	0.003	(0.010)	0.125	(0.157)
WeightExtreme	−1.033*	(0.564)	−0.175**	(0.080)	−2.649	(2.109)
StdDiscount	−6.099	(4.130)	−0.626	(0.732)	−18.352**	(7.662)
PresentBias	−4.306	(3.156)	−0.572	(0.478)	−1.402	(5.983)
Nb. of observations	102		102		57	

*, ** and *** stand for significance at the 10, 5 and 1% level, respectively. The marginal effects are evaluated at the observed values in the dataset and then averaged (average marginal effects). For binary variables, they are computed as the effect of a discrete change from 0 to 1. The standard errors (in parentheses) are adjusted for our survey design. In the case of the intensity equation of the two-part model, we report the marginal effects on the expected values for the outcome conditional on being positive.

Farmer and farm characteristics Significance Wald tests of variables show that farm size (*FarmSize*) and possession of marginal land (*Margin*) increase significantly the probability of miscanthus adoption (respectively at the 1 and 5 per cent level). On average, for a farmers' population like the one from which the sample was drawn, the probability of miscanthus adoption increases by 1.0 percentage point for every supplementary 10 ha farmed. Rämö et al. (2009), Roos et al. (2000), Villamil et al. (2008), and Breen et al. (2009) also found a positive effect of farm size on farmers' willingness to grow energy crops. Yet, in Jensen et al. (2007), the relationship between switchgrass adoption by U.S. Tennessee farmers and farm size was negative. Farm size can be viewed as a proxy for farmers' investment capacity: farmers having more land may have accumulated more savings, and hence be able to invest in miscanthus without needing a credit, which would entail extra costs. Another explanation may lie in the existence of fixed transaction costs such as information-acquisition costs: miscanthus requires an up-front investment in learning, despite the technical assistance offered by processors through production contracts. As for the binary variable *Margin*, farmers having marginal land are, on average, 12 points more likely to participate in miscanthus production than farmers having homogeneous land. This result confirms Hypothesis 1, that is making marginal land more profitable is a major motivation for growing miscanthus.

Contrary to *FarmSize* and *Margin*, *Livestock* has a significant negative effect on adoption (at the 10 per cent level): on average, farmers having livestock are 11 points less likely to adopt miscanthus than field crop specialists. This is in line with Roos et al. (2000), Jensen et al. (2007) and Breen et al.'s (2009) results who showed that breeding was negatively linked with energy-crop adoption. A possible explanation would be that cattle farmers have less land available for conversion to miscanthus. Indeed, marginal land may be used as pasture for cattle feeding, on the farm or outside the farm. If the feeding capacity of the farm greatly exceeds the needs of the cattle, farmers are able to sell hay to other farmers because they are equipped for cutting and conditioning hay. In other words, in cattle systems, marginal land is generally productive. It may be either unavailable in the short-term, or available but quite profitable (more than it would be if used for miscanthus).

Individual preferences Probability weighting (*WeightExtreme*) is the only preference variable having a significant effect on the participation decision (at the 5 per cent level). The marginal effect of *WeightExtreme* on the probability of miscanthus adoption is negative, meaning that the higher farmers overweight extreme events, the lower they tend to adopt miscanthus. This is consistent with the hypothesis made about the distribution of returns from miscanthus and the ensuing Hypothesis 5. We showed in Section 4.3.3 that it was reasonable to think that, compared to a traditional crop such as wheat, miscanthus returns were quite unrisky but did involved extremely unfavorable events like an establishment failure or a contract-counterparty failure. Thus, under this hypothesis, it is logical that *WeightExtreme* decreases miscanthus attractiveness and the probability of its adoption. The effect is rather large, the probability of adoption increasing on average by a 1.8 percentage point if *WeightExtreme* increases by 0.1.

Intensity decision Column 4 of Table 4.5 presents the estimated marginal effects for the intensity equation of the base two-part model, i.e., the effects on the acreage farmers decided to allocate to miscanthus provided that they had decided to participate in this production. The two variables that significantly affect the intensity decision are different from the ones which affect the participation decision, highlighting the importance of considering the participation and the intensity decision as separate ones.

Farmer and farm characteristics The *North* variable is significant at the 5 per cent level, and negatively correlated with miscanthus acreage. On average, farmers who deliver to the *Baigneux-les-Juifs* plant grow 2.6 ha less of miscanthus relative to farmers who supply the *Aiserey* plant. Indeed, the production contracts offered by the dehydratation cooperative of *Baigneux-les-Juifs* do not include any cash-advance system, which could decrease farmers' capacity to invest in miscanthus (the investment is proportional to the surface area). In addition, the pedo-climatic conditions on the plateau where *Baigneux-les-Juifs* is located are less favorable than in the south plain. Thus, farmers may be less confident relative to miscanthus adaptation to local growing conditions, and may prefer to trial it on very small plots to reduce the impact of an establishment failure on their income.

We cannot find any significant effect of *FarmSize*, *Livestock*, or *Margin* on miscanthus acreage whereas the three of them have an impact on the participation decision. The absence of effect from *FarmSize* tends to support the interpretation we made previously about farm size being a proxy for information-acquisition costs (fixed), rather than for investment capacity in plantation costs (variable). In the case of *Livestock* and *Margin*, the absence of effect on miscanthus acreage may seem surprising because both are correlated with the extent of land suitable for miscanthus production (i.e., more profitable than the actual use, and available in the short-term). In fact, because miscanthus is in an early development phase, most farmers adopt miscanthus on small trial plots. Hence, provided they have some land suitable for miscanthus, the area is generally sufficient for trial plots (Abadi Ghadim and Pannell, 1999), and thus the extent of suitable of land is not a binding constraint in the intensity decision. The same explanation could also be invoked for the absence of effect of *FarmSize*. In that case, *FarmSize* would be a proxy for farmers' investment capacity, but the effect would not visible because the liquidity constraint would not be binding.

Individual preferences Our estimations show that the standard discount factor *StdDiscount* tends to decrease adoption intensity significantly (at the 5 per cent level), meaning that long-term discounting would lead to an increase in adoption intensity. In other words, the higher farmers devaluate outcomes occurring in the far future relative to outcomes occurring in the close future,

Table 4.6: Two-part models of miscanthus adoption when accounting for interaction effects

	Model A4			
	Participation		Intensity	
	Coeff.	Std. Err.	Coeff.	Std. Err.
Constant	4.632	(5.409)	37.684**	(17.868)
Farmer characteristics				
Age	−0.025	(0.022)	−0.053	(0.062)
ExtraInc	1.064	(0.710)	2.249	(3.275)
PublicInfo	0.065	(0.106)	0.429	(0.394)
PrivateInfo	−0.009	(0.106)	0.199	(0.456)
Farm characteristics				
FarmSize	0.620***	(0.189)	0.520	(0.785)
LandOwned	−1.409	(0.858)	−2.069	(3.361)
1.Livestock	−0.807*	(0.466)	1.701	(1.701)
1.ExBeet	−0.692	(0.590)	−4.510	(2.931)
1.Margin	0.833*	(0.448)	−5.784*	(3.369)
1.Wood	0.832**	(0.402)	2.528	(1.532)
1.North	0.064	(0.408)	−4.718**	(2.252)
WheatRisk	0.119	(0.286)	0.062	(0.938)
Individual preferences				
1.EnvironObjFirst	0.896	(0.631)	−0.813	(1.879)
VConcavity	0.124	(0.374)	1.512	(1.531)
LossAversion	−0.156*	(0.081)	−0.198	(0.348)
WeightExtreme	−1.553**	(0.626)	−5.447	(4.841)
StdDiscount	−2.760	(3.946)	−26.557**	(10.917)
PresentBias	−3.153	(2.427)	−1.025	(8.834)
LossAversion×1.ExBeet	0.312**	(0.126)	0.662	(0.506)
WeightExtreme×1.ExBeet	0.929	(0.977)	1.783	(5.595)
σ			4.146***	(0.520)
Nb. of observations	102		57	
Model p-value	0.04		0.89	
Prop. correctly predicted	0.90			
Prop. variance explained			0.46	

*, ** and *** stand for significance at the 10, 5 and 1% level, respectively.
The standard errors are adjusted for our survey design.

the more they invest in miscanthus. This result is in opposition with Hypothesis 7 which postulated that farmers with large discount rates (small discount factors) would view miscanthus profitability as low because of the delayed returns, and hence be reluctant to adopt it. However, as highlighted in Section 4.6.3, this result is not robust and may be due to outliers. On the contrary, we cannot find any significant effect of *PresentBias* on adoption intensity.

Interaction effects

Table 4.6 collates the estimates of the two-part model when accounting for the interaction effects of *ExBeet* with *LossAversion* and *WeightExtreme* (model A4). Only the interaction effect of *LossAversion* with *ExBeet* on the participation decision is significant. It is significant at the 5 per cent level and positive, which means that the effect of *LossAversion* is higher for former beet producers than for non former beet producers. This is confirmed by the corresponding

Table 4.7: Marginal effects on miscanthus adoption when accounting for interaction effects

	Model A4			
	Pr(Adopter=1)		E(MiscAcreage|Adopter=1)	
Farmer characteristics				
Age	−0.005	(0.004)	−0.034	(0.041)
ExtraInc	0.190	(0.124)	1.456	(2.116)
PublicInfo	0.012	(0.019)	0.278	(0.256)
PrivateInfo	−0.002	(0.019)	0.129	(0.295)
Farm characteristics				
FarmSize	0.110***	(0.029)	0.337	(0.509)
LandOwned	−0.251*	(0.151)	−1.340	(2.177)
1.Livestock	−0.118**	(0.055)	1.152	(1.198)
1.ExBeet	0.154	(0.095)	−1.143	(1.171)
1.Margin	0.128**	(0.056)	−4.539	(3.014)
1.Wood	0.158**	(0.079)	1.714	(1.087)
1.North	0.012	(0.075)	−2.713**	(1.160)
WheatRisk	0.021	(0.051)	0.040	(0.607)
Individual preferences				
1.EnvironObjFirst	0.200	(0.165)	−0.510	(1.142)
VConcavity	0.022	(0.067)	0.979	(0.996)
LossAversion	−0.003	(0.011)	0.079	(0.175)
WeightExtreme	−0.202***	(0.072)	−2.969	(2.157)
StdDiscount	−0.492	(0.697)	−17.196**	(7.198)
PresentBias	−0.562	(0.429)	−0.664	(5.720)
Marginal effect of LossAversion *for each level of* ExBeet*:*				
LossAversion×0.ExBeet	−0.026*	(0.014)	−0.198	(0.348)
LossAversion×1.ExBeet	0.039	(0.024)	0.464	(0.383)
Marginal effect of WeightExtreme *for each level of* ExBeet*:*				
WeightExtreme×0.ExBeet	−0.256**	(0.110)	−5.447	(4.841)
WeightExtreme×1.ExBeet	−0.155	(0.164)	−3.664	(3.770)
Nb. of observations	102		57	

*, ** and *** stand for significance at the 10, 5 and 1% level, respectively. The marginal effects are evaluated at the observed values in the dataset and then averaged (average marginal effects). For binary variables, they are computed as the effect of a discrete change from 0 to 1. The standard errors (in parentheses) are adjusted for our survey design. In the case of the intensity equation, we report the marginal effects on the expected value for the outcome conditional on being positive.

average marginal effects displayed at the bottom of Table 4.7. The effect of *LossAversion* on the probability of participation is -0.03 and significant if farmers are not former beet producers, whereas it is 0.04 (and non significant) if farmers are former beet producers. The first value tells us that, on average, the participation probability for non ex-beet producers decreases by around 3 points for every increase of 1 unit in the loss aversion parameter. This observation is consistent with Hypothesis 6 which states that farm history is likely to modify the effect of loss aversion on adoption because of a change in the reference point. For non ex-beet producers, the reference point corresponds to the mean wheat return on plain land, or the mean miscanthus return on marginal land. As loss aversion penalizes more the all-loss distributions than the mixed distributions, an increase in loss aversion has opposite effects on adoption depending on the land type: a negative effect on plain land because miscanthus is more penalized than wheat, and a positive effect on marginal land because wheat is more penalized than miscanthus. Hence, the overall negative effect of *LossAversion* on the probability of adoption might suggest that the negative effect of loss aversion on plain land outweighs its positive effect on marginal land. However, former beet producers may be concerned with replacing the incomes from sugar beet, quite high and stable. As a result, they may exhibit a high reference point. It is highly probable that this high reference point only applies to land where beet can be grown, i.e., plain land. On this type of land, ex-beet producers would thus perceive all returns as losses, and an increase in loss aversion would not disfavor one crop more than the other. This is consistent with the absence of any effect of *LossAversion* on adoption.

Alternative sets of regressors

In this section, we test alternative specifications of the two-part model by varying the set of regressors. Compared to the base model A0, in model A1 individual preferences are omitted, in model A2 *PresentBias* is omitted, and in model A3 *Margin* is replaced by *IdleLand*. The estimates of the marginal effects for these three alternative specifications are displayed in Table 4.8.

Participation decision The results obtained from model A0 are robust over the three alternative specifications: we observe similar significant effects of the variables *FarmSize*, *Margin*, *Livestock* and *WeightExtreme*.

Table 4.8: Marginal effects on miscanthus adoption for different sets of regressors

	Model A1 (omitting preferences)		Model A2 (omitting *PresentBias*)		Model A3 (replacing *Margin*)	
	Pr(Ado=1)	E(Misc|Ado=1)	Pr(Ado=1)	E(Misc|Ado=1)	Pr(Ado=1)	E(Misc|Ado=1)
Farmer characteristics						
Age	−0.007**	−0.017	−0.007*	−0.018	−0.009***	0.008
	(0.003)	(0.027)	(0.003)	(0.038)	(0.003)	(0.041)
ExtraInc	0.182*	0.949	0.193	1.652	0.223*	2.386
	(0.102)	(1.316)	(0.125)	(2.114)	(0.119)	(2.168)
PublicInfo	0.006	0.101	0.014	0.291	0.007	0.158
	(0.016)	(0.259)	(0.018)	(0.292)	(0.018)	(0.272)
PrivateInfo	−0.009	0.101	−0.005	0.070	−0.007	0.193
	(0.018)	(0.234)	(0.019)	(0.256)	(0.019)	(0.225)
Farm characteristics						
FarmSize	0.097***	−0.322	0.102***	0.304	0.094***	0.001
	(0.028)	(0.422)	(0.030)	(0.500)	(0.029)	(0.511)
LandOwned	−0.180	−0.827	−0.204	−0.994	−0.090	−2.190
	(0.152)	(2.208)	(0.170)	(2.257)	(0.170)	(2.190)
1.Livestock	−0.102*	1.953	−0.109*	1.215	−0.089	2.737*
	(0.054)	(1.315)	(0.055)	(1.145)	(0.056)	(1.441)
1.ExBeet	0.157**	−0.960	0.116	−1.074	0.121	−0.194
	(0.074)	(1.211)	(0.077)	(1.178)	(0.074)	(1.046)
1.Margin	0.095*	−3.125	0.120**	−4.461		
	(0.055)	(3.563)	(0.059)	(3.238)		
IdleLand					2.102***	36.128***
					(0.766)	(10.575)
PlotSize					0.011	0.181**
					(0.008)	(0.087)
1.Wood	0.107	0.949	0.115	1.642	0.123	2.119*
	(0.069)	(1.054)	(0.074)	(1.072)	(0.076)	(1.107)
1.North	0.042	−1.968	−0.011	−2.561**	−0.094	−3.666***
	(0.069)	(1.222)	(0.072)	(1.212)	(0.069)	(1.158)
WheatRisk	0.022	−0.207	0.017	0.124	0.034	0.399
	(0.048)	(0.594)	(0.052)	(0.651)	(0.054)	(0.682)
Individual preferences						
1.EnvironObjFirst			0.278	−0.584	0.338	−0.248
			(0.203)	(1.064)	(0.205)	(1.134)
VConcavity			0.018	0.597	0.054	0.859
			(0.066)	(0.822)	(0.066)	(0.942)
LossAversion			0.001	0.121	0.001	−0.029
			(0.010)	(0.154)	(0.010)	(0.146)
WeightExtreme			−0.202**	−2.680	−0.141*	−2.483
			(0.083)	(2.137)	(0.078)	(1.912)
StdDiscount			0.031	−17.011**	−0.482	−17.326**
			(0.454)	(6.963)	(0.727)	(7.069)
PresentBias					−0.395	−3.359
					(0.485)	(5.723)
Nb. of observations	105	57	102	57	102	57
Model p-value	0.04	0.72	0.04	0.76	0.09	0.51
Prop. correctly predicted	0.85		0.86		0.85	
Prop. variance explained		0.27		0.43		0.53

*, ** and *** stand for significance at the 10, 5 and 1% level, respectively. The marginal effects are evaluated at the observed values in the dataset and then averaged (average marginal effects). For binary variables, they are computed as the effect of a discrete change from 0 to 1. The standard errors (in parentheses) are adjusted for our survey design. In the case of the intensity equation, we report the marginal effects on the expected values for the outcome conditional on being positive (Ado: *Adopter*, Misc: *MiscAcreage*).

Moreover, in some of these models, new variables appear to have a significant effect. It is the case of the *Age* variable in all three models, which exhibits a quite strong marginal effect on the probability of adoption. On average, the latter decreases by a 7 to 9 points for every 10-year increase in farmers' age. Rämö et al. (2009) and Jensen et al. (2007) found a similar negative effect of age on energy-crop adoption , respectively in Finland and Tennessee, U.S.A.. However, regarding short rotation willow, Roos et al.'s (2000) results are ambiguous. Farmers under 35 years and above 65 years were found to grow willow on a smaller surface area than the others, whereas farmers between 50 and 65 years were found to grow willow on a larger area. Possible explanations for the negative effect of age on technology adoption are twofold, one reason is psychological and the other one economic. First, as highlighted in the general literature about technology adoption, elder people tend to be more resistant to change because of the burden of habits. Second, elder farmers are closer to retirement than younger ones, thus their planning horizon is shorter and a long-term investment is less profitable for them.

In model A1, when individual preferences are omitted, *ExBeet* also exhibits a significant marginal effect on participation (at the 5 per cent level), which equals 0.16. It means that former sugar-beet producers are more prone to adopt miscanthus than non ex-beet producers. They may be motivated by higher expected benefits because most of them are shareholders of the *Aiserey* dehydration plant. In addition, fixed transaction costs such as information gathering may be minimized because they were directly targeted by the regional diversification plan. Last, the positive effect of *ExBeet* on participation is consistent with the high reference-point explanation given earlier.

In model A2, we omitted the *PresentBias* variable due to suspicions of collinearity with *StdDiscount*, which may bias the estimates of model A0. However, in the end, this concern does not seem to be relevant as model A2 leads to similar results than model A0.

In model A3, we replaced *Margin* by *IdleLand* and *PlotSize* in order to use objective and absolute description criteria for marginal land rather than a subjective and relative single criterion. We found that, on average, every increase of 1 point in the proportion of voluntary idle land increases significantly (at the 1 per cent level) miscanthus adoption by 2 percentage points. The rationale may be quite the same that the one for *Margin*, that is farmers view miscanthus as a mean of making unproductive land profitable. However, *PlotSize* has no significant effect on participation, which suggests that marginal land does not only refer to plots with unfavorable dimensions (or more generally an unfavorable geometry). As shown in Chapter 2, marginal land rather refers to plots with poor growing conditions. The results obtained from model A3 further confirm that our characterization of marginal land through farmers' declarations is reliable to obtain a proxy for low-productivity land (idle land is an extreme case of low-productivity land).

We were not able to report any significant effect of the preference variable *EnvironObjFirst* in any of the models for the participation decision. It is a common finding for sustainability-related innovations, environmental benefits being generally of secondary importance in determining the economic attractiveness of such innovations to farmers (Pannell, 1999; Bathgate and Pannell, 2002).

Time preferences (*StdDiscount* and *PresentBias*) were never found to have a significant effect on participation either. It may be due to the fact that, in *Bourgogne*, miscanthus establishment costs are heavily subsidized by the regional diversification plan .

Intensity decision The marginal negative effects of *North* and *StdDiscount* on adoption intensity estimated with model A0 are robust over the alternative specifications A2 and A3.

Furthermore, in model A3, some new effects appear to be significant. First, *Livestock* has a (weakly) positive effect on the intensity decision, which contrasts with its negative effect on the participation decision. It suggests that, once cattle farmers have decided to participate in miscanthus production because they have suitable land, they tend to allocate more land to the new crop than farmers who are not breeders.

Second, *IdleLand* exhibits a significant positive effect on adoption intensity at the 1 per cent level. This means that the proportion of idle land is a binding constraint for miscanthus extension, whereas the proportion of marginal land is not. This result supports the theoretical prediction that farmers allocate first idle land to miscanthus because it is where they can obtain the highest (relative) profit. As the area of idle land per farm is very low, it is binding even with small miscanthus surface areas. Similarly, *PlotSize* has a significant positive effect on adoption intensity, whereas it is not determinant in explaining participation. An explanation could be that, at the farm-level, the allocation of land to miscanthus is a plot-by-plot process. Indeed, in the overwhelming majority of cases, the allocation of plots to miscanthus follows an all-or-nothing rule. Thus, the higher the mean plot size, the higher the total miscanthus acreage on the farm, but there is no effect on the probability of adoption.

Unlike the participation decision, the intensity decision can be explained by the *Age*, *ExBeet*, or risk-preference variables in any of the models. We were not able either to report any significant effect of *EnvironObjFirst* on the intensity decision whatever the specification (the situation being the same with the participation decision).

4.6.2 Adoption according to the type of land

Full set of regressors and alternative sets

Table 4.9 collates the coefficient estimates of the bivariate probit model explaining farmers' decision (i) to adopt miscanthus on marginal land and (ii) to adopt miscanthus on plain land (model L0). The corresponding average marginal effects are displayed in Table 4.10. The effects on the probability of adoption whatever the land type are in column 2, those on the probability of adoption on marginal land in column 4, and those on the probability of adoption on plain land in column 6. With this base specification of the bivariate probit model, the proportion of correctly predicted outcomes is 86% for adoption on any land, 87% for adoption on marginal land, and 91% for adoption on plain land. The first percentage is to be compared with the proportion of correctly predicted binary outcomes by model A0 (participation equation), that is to say 81%. Thus, the bivariate probit is slightly better to explain overall participation than the two-part model.

Regarding explanatory variables, we should first of all note that model L0 gives results that are consistent with the ones from the participation equation of model A0. Indeed, we also find that *Age*, *FarmSize*, *Livestock*, and *WeightExtreme* have a significant effect on the probability of adoption, whatever the type of land (column 2 of Table 4.10). The signs of the effects are as expected. However, model L0 sheds light on the differences between the explanatory variables for adoption on marginal land and adoption on plain land.

Indeed, several variables exhibit a significant effect on the probability of adopting miscanthus on one type of land only: *Age*, *ExtraInc*, *Livestock* and *StdDiscount* on marginal land only, *ExBeet* and *WeightExtreme* on plain land only. From columns 2, 4 and 6 of Table 4.11, it can be observed that this result is robust for all variables with the exception of *StdDiscount*.[40]

40. In specifications L1 and L2, the variable *Margin* is omitted in the equation explaining adoption on marginal land because, obviously, all farmers allocating marginal land to miscanthus do have some.

Table 4.9: Model of miscanthus adoption according to type of land

	Model L0 (bivariate probit)					
	Participation (MarginUsed)		Participation (PlainUsed)		arc tanh ρ	
	Coeff.	Std. Err.	Coeff.	Std. Err.	Coeff.	Std. Err.
Constant	8.815*	(5.161)	−1.644	(5.565)	0.316*	(0.189)
Farmer characteristics						
Age	−0.035*	(0.019)	−0.031	(0.019)		
ExtraInc	1.131*	(0.646)	0.795	(0.706)		
PublicInfo	0.123	(0.099)	−0.062	(0.097)		
PrivateInfo	−0.105	(0.101)	0.018	(0.098)		
Farm characteristics						
FarmSize	0.410***	(0.149)	0.480***	(0.178)		
LandOwned	−0.342	(0.766)	−1.119	(1.037)		
1.Livestock	−0.712**	(0.357)	−0.277	(0.429)		
1.ExBeet	0.241	(0.339)	0.877**	(0.406)		
1.Margin						
1.Wood	0.456	(0.343)	0.600	(0.372)		
1.North	−0.087	(0.364)	0.232	(0.402)		
WheatRisk	−0.041	(0.252)	0.299	(0.291)		
Individual preferences						
1.EnvironObjFirst	0.245	(0.575)	0.382	(0.748)		
VConcavity	0.527	(0.409)	−0.133	(0.336)		
LossAversion	0.019	(0.052)	0.017	(0.057)		
WeightExtreme	−0.393	(0.399)	−0.992*	(0.503)		
StdDiscount	−6.744*	(3.603)	1.575	(3.731)		
PresentBias	−3.315	(2.302)	−1.760	(2.505)		
1.Margin			0.092	(0.445)		
ρ	0.306					
Nb. of observations	102					
Model p-value	0.06					
P. c. p. (any land)	0.86					
P. c. p. (marginal land)	0.87					
P. c. p. (plain land)	0.91					

*, ** and *** stand for significance at the 10, 5 and 1% level, respectively. The standard errors are adjusted for our survey design. Because arc tanh(0) = 0, the reported Wald test for arc tanh $\rho = 0$ is equivalent to the test for $\rho = 0$, i.e., the errors terms are correlated.

Table 4.10: Marginal effects on miscanthus adoption according to type of land

	Model L0 (bivariate probit)					
	1-Pr(MarginUsed=1,PlainUsed=1)		Pr(MarginUsed=1)		Pr(PlainUsed=1)	
Constant						
Farmer characteristics						
Age	−0.007**	(0.003)	−0.005*	(0.003)	−0.004	(0.002)
ExtraInc	0.217*	(0.112)	0.177*	(0.098)	0.096	(0.086)
PublicInfo	0.010	(0.017)	0.019	(0.015)	−0.008	(0.012)
PrivateInfo	−0.012	(0.016)	−0.016	(0.016)	0.002	(0.012)
Farm characteristics						
FarmSize	0.096***	(0.026)	0.064***	(0.022)	0.058***	(0.019)
LandOwned	−0.145	(0.157)	−0.054	(0.120)	−0.135	(0.124)
1.Livestock	−0.098*	(0.052)	−0.092**	(0.039)	−0.031	(0.045)
1.ExBeet	0.121	(0.076)	0.039	(0.057)	0.118*	(0.061)
1.Margin	0.008	(0.038)			0.011	(0.051)
1.Wood	0.118*	(0.068)	0.076	(0.061)	0.079	(0.054)
1.North	0.012	(0.068)	−0.013	(0.054)	0.030	(0.055)
WheatRisk	0.022	(0.043)	−0.007	(0.039)	0.036	(0.035)
Individual preferences						
1.EnvironObjFirst	0.075	(0.102)	0.043	(0.112)	0.055	(0.127)
VConcavity	0.055	(0.067)	0.083	(0.062)	−0.016	(0.040)
LossAversion	0.004	(0.009)	0.003	(0.008)	0.002	(0.007)
WeightExtreme	−0.140*	(0.073)	−0.062	(0.063)	−0.120**	(0.059)
StdDiscount	−0.719	(0.606)	−1.058**	(0.524)	0.190	(0.448)
PresentBias	−0.583	(0.383)	−0.520	(0.348)	−0.212	(0.304)
Nb. of observations	102		102		102	

*, ** and *** stand for significance at the 10, 5 and 1% level, respectively. The marginal effects are evaluated at the observed values in the dataset and then averaged (average marginal effects). For binary variables, they are computed as the effect of a discrete change from 0 to 1. The standard errors (in parentheses) are adjusted for our survey design.

The reason why *Age* and *ExtraInc* have an effect on adoption on marginal land, but not on plain land is unclear. However, the effect is only weakly significant at the 10 per cent level.

The difference in the significancy of *Livestock* between marginal land and plain land is more striking. On marginal land, cattle breeders are 9 points less likely to adopt miscanthus than farmers who only have cropping activities. This effect, significant at the 5 per cent level, confirms that many cattle breeders may not view miscanthus production as an attractive activity because their marginal land is already used for fodder. Marginal plots are in fact already productive and needed in the short term.[41] As we could not find any significant effect of *Livestock* on adoption probability on plain land, breeding cattle could not only decrease the overall probability of adoption, but also decrease the proportion of marginal land allocated to miscanthus relative to plain land.[42]

As respects *ExBeet*, our results suggest that being a former beet producer impacts adoption

41. In the longer term, some farmers may decide to reduce their cattle and allocate the land made available to miscanthus.

42. This last result is to be confirmed because the marginal effect of *Livestock* on the probability of adoption on plain land is negative although not significant.

Table 4.11: Marginal effects on miscanthus adoption according to type of land for different sets of regressors

	Model L1 (omitting preferences)		Model L2 (omitting *PresentBias*)		Model L3 (replacing *Margin*)	
	Pr(MUsed=1)	Pr(PUsed=1)	Pr(MUsed=1)	Pr(PUsed=1)	Pr(MUsed=1)	Pr(PUsed=1)
Farmer characteristics						
Age	−0.007**	−0.003	−0.006**	−0.004*	−0.006*	−0.004*
	(0.003)	(0.002)	(0.003)	(0.002)	(0.003)	(0.002)
ExtraInc	0.131*	0.081	0.159*	0.088	0.174*	0.080
	(0.079)	(0.072)	(0.095)	(0.085)	(0.099)	(0.079)
PublicInfo	0.007	−0.004	0.019	−0.009	0.019	−0.013
	(0.013)	(0.011)	(0.016)	(0.012)	(0.015)	(0.013)
PrivateInfo	−0.013	0.000	−0.016	0.004	−0.017	0.001
	(0.015)	(0.011)	(0.015)	(0.012)	(0.016)	(0.012)
Farm characteristics						
FarmSize	0.058***	0.059***	0.068***	0.059***	0.065***	0.053***
	(0.021)	(0.017)	(0.022)	(0.019)	(0.022)	(0.018)
LandOwned	−0.040	−0.153	−0.071	−0.141	−0.053	−0.123
	(0.111)	(0.111)	(0.125)	(0.125)	(0.122)	(0.121)
1.Livestock	−0.087**	−0.027	−0.096**	−0.032	−0.093**	−0.005
	(0.037)	(0.044)	(0.040)	(0.045)	(0.040)	(0.050)
1.ExBeet	0.067	0.140**	0.043	0.122*	0.039	0.137**
	(0.054)	(0.059)	(0.058)	(0.062)	(0.057)	(0.060)
1.Margin	.	−0.006	.	0.011		
		(0.046)		(0.050)		
IdleLand					.	0.949*
						(0.540)
PlotSize					.	0.007
						(0.005)
1.Wood	0.074	0.084*	0.098	0.087	0.077	0.083
	(0.054)	(0.048)	(0.065)	(0.054)	(0.061)	(0.054)
1.North	0.018	0.050	−0.008	0.035	−0.014	−0.021
	(0.054)	(0.056)	(0.055)	(0.056)	(0.055)	(0.056)
WheatRisk	0.001	0.030	−0.008	0.038	−0.007	0.048
	(0.037)	(0.031)	(0.040)	(0.035)	(0.040)	(0.037)
Individual preferences						
1.EnvironObjFirst			0.059	0.063	0.041	0.057
			(0.118)	(0.133)	(0.115)	(0.134)
VConcavity			0.063	−0.025	0.080	−0.027
			(0.059)	(0.040)	(0.061)	(0.038)
LossAversion			0.001	0.001	0.003	0.002
			(0.008)	(0.007)	(0.008)	(0.006)
WeightExtreme			−0.082	−0.130**	−0.061	−0.088
			(0.065)	(0.061)	(0.063)	(0.057)
StdDiscount			−0.494	0.429	−1.050*	0.206
			(0.368)	(0.317)	(0.533)	(0.429)
PresentBias					−0.502	−0.142
					(0.358)	(0.280)
ρ						
Nb. of observations	105	105	102	102	102	102
Model p-value	0.01	.	0.03	.	0.03	.
P. c. p. (any land)	0.85		0.85		0.86	
P. c. p. (marginal land)	0.88		0.87		0.87	
P. c. p. (plain land)		0.89		0.91		0.90

*, ** and *** stand for significance at the 10, 5 and 1% level, respectively. The marginal effects are evaluated at the observed values in the dataset and then averaged (average marginal effects). For binary variables, they are computed as the effect of a discrete change from 0 to 1. The standard errors (in parentheses) are adjusted for our survey design. MUsed: *MarginUsed*, PUsed: *PlainUsed*.

Table 4.12: Model of miscanthus adoption according to type of land when accounting for interaction effects

	Model L4					
	Participation (MarginUsed)		Participation (PlainUsed)		arc tanh ρ	
	Coeff.	Std. Err.	Coeff.	Std. Err.	Coeff.	Std. Err.
Constant	8.768*	(5.117)	−3.200	(5.807)	0.298	(0.212)
Farmer characteristics						
Age	−0.034*	(0.019)	−0.041*	(0.023)		
ExtraInc	1.188*	(0.676)	0.653	(0.774)		
PublicInfo	0.100	(0.105)	−0.135	(0.111)		
PrivateInfo	−0.091	(0.102)	0.040	(0.106)		
Farm characteristics						
FarmSize	0.429***	(0.143)	0.652***	(0.220)		
LandOwned	−0.416	(0.756)	−1.795*	(1.050)		
1.Livestock	−0.695*	(0.369)	−0.580	(0.559)		
1.ExBeet	−0.140	(0.525)	−0.946	(0.660)		
1.Margin			0.082	(0.443)		
1.Wood	0.553	(0.363)	1.126***	(0.422)		
1.North	−0.008	(0.355)	0.343	(0.488)		
WheatRisk	−0.016	(0.260)	0.389	(0.363)		
Individual preferences						
1.EnvironObjFirst	0.160	(0.591)	0.319	(0.745)		
VConcavity	0.500	(0.414)	−0.179	(0.443)		
LossAversion	−0.034	(0.062)	−0.288***	(0.101)		
WeightExtreme	−0.414	(0.573)	−2.423***	(0.836)		
StdDiscount	−6.539*	(3.599)	4.276	(3.979)		
PresentBias	−3.434	(2.274)	−1.372	(2.486)		
LossAversion×1.ExBeet	0.127	(0.091)	0.460***	(0.127)		
WeightExtreme×1.ExBeet	−0.087	(0.944)	1.939*	(1.048)		
ρ	0.290					
Nb. of observations	102					
Model p-value	0.02					
P. c. p. (any land)	0.89					
P. c. p. (marginal land)	0.87					
P. c. p. (plain land)	0.92					

*, ** and *** stand for significance at the 10, 5 and 1% level, respectively. The standard errors are adjusted for our survey design. Because $\text{arc tanh}(0) = 0$, the reported Wald test for $\text{arc tanh}\,\rho = 0$ is equivalent to the test for $\rho = 0$, i.e., the errors terms are correlated.

on plain land mainly. Indeed, it can be argued that their high income expectations are not valid for marginal land where they never grew sugar beet. As postulated before, their high reference point is specific to plain land. Other interpretations can be invoked for growing miscanthus on plain land, such as the wish to obtain high yields. As former beet producers are more involved in the development of miscanthus production, they may want to set an example for other farmers or replicate rhizomes.

As regards *WeightExtreme*, it is likely that it does not impact adoption on marginal land because on such land both miscanthus and wheat exhibit extreme events. Thus, the overweighting of extreme events is not as unfavorable to miscanthus as on plain land.

Table 4.13: Marginal effects on miscanthus adoption according to type of land when accounting for interaction effects

	Model L4					
	1-Pr(MarginUsed=1,PlainUsed=1)		Pr(MarginUsed=1)		Pr(PlainUsed=1)	
Farmer characteristics						
Age	−0.008**	(0.003)	−0.005*	(0.003)	−0.004*	(0.002)
ExtraInc	0.201*	(0.111)	0.183*	(0.101)	0.069	(0.081)
PublicInfo	0.002	(0.017)	0.015	(0.016)	−0.014	(0.011)
PrivateInfo	−0.008	(0.016)	−0.014	(0.016)	0.004	(0.011)
Farm characteristics						
FarmSize	0.106***	(0.024)	0.066***	(0.021)	0.069***	(0.021)
LandOwned	−0.194	(0.143)	−0.064	(0.117)	−0.189*	(0.108)
1.Livestock	−0.112**	(0.050)	−0.089**	(0.040)	−0.054	(0.047)
1.ExBeet	0.169*	(0.092)	0.055	(0.065)	0.164*	(0.084)
1.Margin	0.006	(0.034)			0.008	(0.045)
1.Wood	0.172**	(0.068)	0.093	(0.066)	0.139**	(0.062)
1.North	0.030	(0.069)	−0.001	(0.055)	0.040	(0.063)
WheatRisk	0.029	(0.044)	−0.002	(0.040)	0.041	(0.037)
Individual preferences						
1.EnvironObjFirst	0.050	(0.091)	0.027	(0.105)	0.038	(0.101)
VConcavity	0.049	(0.067)	0.077	(0.062)	−0.019	(0.046)
LossAversion	−0.001	(0.010)	0.003	(0.008)	−0.004	(0.007)
WeightExtreme	−0.165**	(0.069)	−0.070	(0.063)	−0.145**	(0.056)
StdDiscount	−0.485	(0.577)	−1.009*	(0.518)	0.450	(0.416)
PresentBias	−0.541	(0.350)	−0.530	(0.340)	−0.144	(0.263)
Marginal effect of LossAversion *for each level of* ExBeet*:*						
LossAversion×0.ExBeet	−0.024*	(0.012)	−0.005	(0.009)	−0.026**	(0.012)
LossAversion×1.ExBeet	0.037*	(0.019)	0.018	(0.017)	0.032*	(0.016)
Marginal effect of WeightExtreme *for each level of* ExBeet*:*						
WeightExtreme×0.ExBeet	−0.214*	(0.111)	−0.058	(0.084)	−0.218**	(0.103)
WeightExtreme×1.ExBeet	−0.133	(0.127)	−0.098	(0.128)	−0.090	(0.116)
Nb. of observations	102		102		102	

*, ** and *** stand for significance at the 10, 5 and 1% level, respectively. The marginal effects are evaluated at the observed values in the dataset and then averaged (average marginal effects). For binary variables, they are computed as the effect of a discrete change from 0 to 1. The standard errors (in parentheses) are adjusted for our survey design.

Interaction effects

Table 4.12 collates the estimates of the bivariate probit model when accounting for the interaction effects between *ExBeet* and *LossAversion* or *WeightExtreme* (model L4). In Table 4.13 are displayed the corresponding marginal effects. As far as plain land is concerned, the effect of the interaction between *ExBeet* and *LossAversion* is similar to that obtained with the participation equation of model A4, although even more significant. In model L4, the marginal effect of *LossAversion* on adoption probability on plain land is estimated to be -0.03 for non ex-beet producers and +0.03 for ex-beet producers. Such an effect is not observed for marginal land because, as explained before, reconversion from beet can be associated with high income expectations on plain land only.

Regarding the interaction effect between *ExBeet* and *WeightExtreme*, it is significant in model L4 for plain land whereas it was not significant in model A4. In model L4, the marginal effect of *WeightExtreme* on adoption probability on plain land is estimated to be -0.22 for non ex-beet producers and -0.09 for ex-beet producers. It means that

The interaction effect shows that, on plain land, high levels of probability distortion are a barrier to adoption mostly for non ex-beet producers. Indeed, it is likely that ex-beet producers have a more favorable representation of miscanthus incomes as far as extreme events are concerned. As they are shareholders of *Aiserey* dehydratation plant, they may be more informed about the plant commercial strategy, or more confident, and thus may not be worried about the counterparty risk. We may not observe such an interaction effect on marginal land because, as above-mentioned, competing land uses such as wheat also exhibit extremely unfavorable events on marginal land.

4.6.3 Robustness and misspecification checks

We intended to detect potential multicollinearity in the base set of explanatory variables by computing the variance inflation factor (VIF) for each variable. This diagnostic statistic consists in computing $1/(1-R^2)$ for each coefficient in a simple regression, R^2 being the coefficient of determination. The VIF for a variable gives the increase in the variance of the coefficient that can be due to non-orthogonality with other variables (Greene, 2008, p.60). Results are given in Table E.1. As all coefficients are lower than 10, we argue than there is no major multicollinearity problem.[43]

To check the robustness of models A0 and L0 to sampling and outliers, we ran the same estimations (i) on a random sub-sample representing 80% of the full sample (models A5 and L5), and (ii) after suppressing the 3 farmers growing more than 20 ha of miscanthus (models A6 and L6). Results are reported in Table E.2 for models A5 and A6, and Table E.3 for models L5 and L6 (Appendix E). Results are not fundamentally different from those obtained with the base specifications A0 and L0, apart for those relative to the intensity equation of A0. Indeed, the marginal effects of the *North* and *StdDiscount* variables become unsignificant. It may be due to the difficulty of obtaining reliable estimates with very small samples. It could also mean than the weight of the 3 outliers in explaining adoption intensity may be over-inflated. An interesting way of correcting for it may have been to use a log-normal specification.[44]

We also checked for a potential nonnormality and heteroscedasticity of the residuals from the tobit model T and from the intensity equation of model A0. Let us begin with the tobit model. The quantile-quantile plot of the residuals against the inverse normal distribution (Figure E.1, Appendix E) shows that the hypothesis of normality of the error terms is justified. The scatter plot of the residuals against the dependent varible *MiscAcreage* (Figure E.2, Appendix E) also denotes that error terms can be assumed to be homoscedastic if the 3 outliers are discarded. Let us now turn to the intensity equation of the two-part model A0. The base assumptions of normality and homoscedasticity are less relevant(Figures E.3 and E.4 of Appendix E). In both type of models, a log-normal specification may have improved the relevancy of the hypotheses about the error terms.

4.7 Conclusion

We mixed survey and experimental data to investigate the impact of individual risk and time preferences on the adoption of perennial energy crops by farmers in *Bourgogne*, France. Risk and time preferences were elicited from behavioural models, namely prospect theory and hyperbolic discounting.

43. As the VIF of *StdDiscount* and *PresentBias* are quite high compared to the VIF of the other variables, we checked in Sections 4.6.1 and 4.6.2 the robustness of our results to the omission of *PresentBias* (models A2 and L2 respectively).

44. See the *log-normal hurdle models* described by Woolridge (2010).

Our results demonstrate that farmers faced with the decision to adopt perennial energy crops display a different behaviour depending on their degree of loss aversion and probability distortion. The more loss averse the farmer, and the more weight extreme events are given, the less likely is miscanthus adoption. However, the effect of loss aversion is highly dependent on farmers' reference level, which may be related to farm history. We showed that the negative effect of loss aversion on adoption did not hold if farmers had high income expectations. Furthermore, our results highlight the importance of taking land-type information into consideration when assessing the impact of PT risk preferences on adoption. Indeed, because perennials are generally less profitable than annuals on plain land, but more profitable on marginal land, we found that loss aversion had a negative effect on adoption on plain land only. In addition, because extremely unfavorable outcomes are likely for both perennials and annuals on marginal land, we found that probability weighting had a negative effect on adoption on plain land only as well.

We were not able to show empirically any robust effect of time preferences on adoption, possibly because in the area under study farmers are offered large plantation subsidies as well as cash-advance systems through production contracts. The results also show that farm characteristics are relevant when investigating the adoption of a new crop. The proportion of low-profitability land (marginal or idle) has a strong positive effect on adoption. On the contrary, cattle farmers are less prone to adopt perennial energy crops than grain farmers.

Our use of behavioural models to examine the adoption of perennial energy crops by farmers in *Bourgogne* reveals results that standard decision models cannot provide. Prospect theory holds promise for deepening our understanding of the process leading to the adoption of perennial plant systems in general, and other innovations yielding similar characteristics. Rank-dependent models may be successfully applied to innovations yielding unlikely extreme outcomes, an establishment failure for instance, and sign-dependent models may shed new light on the adoption process of innovations with land-specific performances, due to resiliency for instance.Understanding drivers of and barriers to perennial crop adoption would be highly relevant for food and ecosystem security (Glover et al., 2010; Pannell, 2001a; Bathgate and Pannell, 2002). Furthermore, our study contributes to the debate about the external validity of experimental measures (Roe and Just, 2009). By finding a significative relationship between farmers' real behavior and farmers' risk preferences as measured in a within-sample experiment, we support the use of experimental field measures to inform decision-making. Our findings have also important implications for the design of policies aiming at enhancing energy-crop production in a sustainable way. First, we recommend policymakers and processors to target areas where farmland is heterogeneous, adoption being more probable on marginal land than on plain land. Second, unfavorable extreme events such as an establishment or a counterparty failure deserve a special attention. Actions ensuring either a reduction of the objective probability of such events or a diminution of their potential consequence on farmers' income may be an effective way of increasing the the total area of perennial energy crops. For instance, regarding the risk of an establishment failure, we recommend that public or private extension services encourage farmers to grow the perennial crops where pedo-climatic conditions have been proved to be acceptable. Promoting these crops in areas where growing conditions are too drastic or untested may be useless because farmers would be paralyzed by the fear of loosing the whole plantation. As already offered in some contracts, processors may also include a special clause allowing for the share of the plantation costs with farmers in case of a crop failure. As regard the risk of a default from the contract counterparty, we encourage contractors to secure outlets for farmers' biomass. Processors may enhance farmers' trust by presenting a credible long-term strategy relative to their activities based on local biomass. They could also sign up a partnership with other buyers, each partner committing to buy each other's feedstock in the event of one partner's failure. Third, risk-reduction measures relative to perennial energy crops may have opposite effects in terms of supply and sustainability. If reducing the impact of extreme events could increase overall adoption, it would be also likely to decrease overall sustainability by increasing the total proportion of plain land allocated to perennials relative to marginal land. As a consequence, risk-reduction measures should be assessed based on a trade-off analysis between supply security and bioenergy sustainability.

Some limitations of this study suggest directions for further research. To begin with, the number of observations in the sample is quite low. Increasing the sample size may have led to more clear-cut conclusions and may have revealed some other significant relationships. In particular, we would have been able to control for more farm and land types. A small sample is a common drawback of quantitative studies when the data come from face-to-face surveys, due to the high cost of collecting information, especially in developed countries. However, in our view, relying on experimental preference measures definitely outweighs the disadvantages of a small sample size.

Then, one may argue that our control of farmers' reference point is quite weak because we used a proxy (whether farmers are former beet producers) which is subject to different interpretations. Though, it is crucial to properly assess the impact of reference-dependent preferences on adoption because of interaction effects. An option to obtain a clean measure of farmers' income expectations would have been to directly ask farmers what their income targets are, but self-reported data are known to suffer from serious biases when mental contents are concerned. Further research is needed on methodologies that could deliver accurate measures of reference points and, improve the construct validity of empirical studies testing for reference-dependent preferences.

Another threat to the validity of our results is their exportability to other locations and times, provided that they are drawn from a single region, only recently concerned by perennial energy crops. About location-specificity, our results apply to areas where farms are quite diversified and farmland is heterogeneous. In that setting, the higher performance of perennials compared to annuals on marginal land than on plain land, in terms of mean profitability and risk attributes, is likely to be the main motivation for adopting perennial energy crops. Other motives may dominate in other contexts. For instance, income diversification was found to be the first driver for adoption in the cereal farms of central France (Bocquého (2008) and Chapter 1). About time-specificity, the determinants of adoption are expected to change with time (Feder and Umali, 1993). We argue that the diffusion of perennial energy crops will reduce the impact of land type on adoption because marginal land will be less and less available. In addition, because biomass markets are likely to expand and skills about perennials to improve, we expect extreme events and probability weighting to lose importance in the adoption process. Furthermore, as plantation subsidies are usually suppressed after a few years, impatience and liquidity constraints may gain significativeness as potential barriers to adoption in late development phases. However, the early development phase is worth studying even in a long-term perspective. As argued by Pannell (1999), farmers implement new crops as small-scale trials before switching to full-scale adoption. Covering more areas, leading cross-country studies, and repeating analyses at different time periods are ways to provide more general insights on the role of farmers' preferences on miscanthus adoption.

Overall, the comprehension of risk issues in technology adoption and of the role of farmers' heterogeneity could be fine-tuned by developing methodologies for probability assessment, as called for by Hardaker and Gudbrand (2010). Our findings suggest more thorough investigations in two directions. The first one would be to provide contrasted probability distributions according to land type. The second one would be to refine the elicitation of distribution tails and farmers' reference point.

Conclusion générale

Dans cette thèse nous nous sommes posée deux questions de recherche : quelles sont les motivations des agriculteurs pour adopter les herbacées pérennes énergétiques ? quel est le rôle joué par l'hétérogénéité des agriculteurs dans l'adoption, en particulier les différences dans leurs préférences par rapport au risque et au temps ?

Au terme de nos recherches, nous obtenons les résultats suivants.

- Premièrement (Chapitre 1), d'après nos modèles normatifs d'adoption, les dispositifs publics ou privés intégrant un prix garanti à long terme et/ou des facilités de financement seraient de puissant moyens de contrer l'effet négatif de deux attributs originaux des herbacées pérennes énergétiques : le caractère émergent du marché de la biomasse-énergie et la longueur du cycle de production. Ces dispositifs (contrats de production par exemple) donnent en principe aux herbacées pérennes un intérêt comme cultures de diversification pour réduire le risque global au niveau de l'exploitation, ce qui compense une rentabilité moyenne inférieure à celle des cultures annuelles traditionnelles. La surface allouée aux plantes pérennes devrait alors être d'autant plus élevée que les agriculteurs sont plus averses au risque (au sens de la théorie de l'utilité espérée de von Neumann and Morgenstern (1947)), contrairement à ce qui est souvent postulé lorsque l'effet des contrats de production n'est pas pris en compte. La surface allouée devrait également être d'autant plus élevée que les agriculteurs sont plus patients et moins averses aux fluctuations intertemporelles.
- Deuxièmement (Chapitre 2), les agriculteurs perçoivent bien la forte incertitude sur les débouchés (en l'absence de contrats de production) et les besoins en trésorerie en début de cyle de production comme les deux principaux effets des herbacées pérennes énergétiques sur l'exploitation. Par contre, en présence de contrats long terme, les herbacées pérennes sont vues comme globalement moins risquées que les cultures traditionnelles, ce qui confirme les résultats

issus des simulations du Chapitre 1. Cependant, des risques extrêmement défavorables en termes de revenu mais peu probables, comme un échec de l'implantation de la culture ou un défaut de la contrepartie du contrat, sont clairement identifiés comme propres aux herbacées pérennes.

- Troisièmement, en moyenne, les agriculteurs se conforment aux modèles de comportement décrits par la théorie des perspectives de Tversky and Kahneman (1992) (Chapitre 3) et l'actualisation hyperbolique de Loewenstein and Prelec (1992) (Chapitre 4). Ainsi, face à des choix risqués, ils ont le goût du risque dans le domaine des pertes, ils sont averses aux pertes, et surestiment les événements extrêmes. Face à des choix intertemporels, ils ont tendance à dévaluer les événements du futur proche à un taux plus élevé que les événements d'un futur éloigné.
- Quatrièmement (Chapitre 4), la probabilité d'adoption des herbacées pérennes énergétiques dépend du degré d'aversion à la perte des agriculteurs et de l'ampleur avec laquelle ils surestiment les événements extrêmes. L'effet de l'aversion à la perte dépend du point de référence des agriculteurs, qui peut être lié au type de terre ou à l'histoire de l'exploitation. L'effet de la surestimation des événements extrêmes dépend du type de terre essentiellement. La probabilité d'adoption sur des terres non-marginales est d'autant plus faible que les agriculteurs sont plus averses aux pertes et donnent plus de poids aux événements extrêmes.[45]
- Cinquièmement (Chapitre 4), la rusticité et l'extensivité en opérations culturales sont des atouts du miscanthus pour son adoption. Ils lui donnent un avantage important dans la valorisation des terres marginales des exploitations, relativement aux cultures traditionnelles. La probabilité d'adoption est d'autant plus forte que la proportion de terres marginales sur l'exploitation est élevée, et que ces terres marginales ne sont pas déjà valorisées par une activité d'élevage.

Ces résultats permettent de répondre aux deux points de notre problématique de recherche :

1. Les agriculteurs ont deux principale motivations pour adopter les herbacées pérennes énergétiques (sous contrat de production) : diversification des activités dans une perspective de gestion des risques et meilleure valorisation des terres marginales. La première motivation concerne surtout des exploitations peu diversifiées au parcellaire homogène, la seconde

45. Les terres marginales correspondent à des terres de qualité inférieure ou sur lequelles les opérations culturales sont plus coûteuses.

des exploitations au parcellaire hétérogène dans lequel des terres marginales peuvent être identifiées.

2. Le rôle que jouent les préférences individuelles par rapport au risque dans l'adoption (sous contrat de production) dépend de la motivation dominante (et donc du type d'exploitation). Si c'est la diversification des activités, l'aversion au risque augmente la probabilité d'adoption. Si c'est la valorisation des terres marginales, alors l'aversion à la perte et la surestimation des événements extrêmes sont les éléments de préférence par rapport au risque qui ont un effet significatif. Ils donnent tous les deux un avantage aux terres marginales par rapport aux terres non marginales, car les revenus issus des cultures pérennes y sont vus comme des gains plutôt que des pertes, et les événements extrêmes ne sont pas vus comme spécifiques aux cultures pérennes. Par ailleurs, quelque soit la motivation dominante, les préférences par rapport au temps, c'est-à-dire impatience et aversion aux fluctuations intertemporelles, sont des freins à l'adoption.

Nos résultats, issus d'un travail empirique sur deux régions différentes, Centre et Bourgogne, sont potentiellement généralisables à grand nombre d'exploitations et de régions. Néanmoins, nos entretiens avec les agriculteurs nous ont appris que la simplification du travail pouvait aussi être à l'origine de l'adoption des herbacées pérennes énergétiques. Dans les régions étudiées, il s'agit pour l'instant d'une motivation minoritaire qui concerne surtout des agriculteurs proches de la retraite ou en double-activité. Dans les régions d'élevage comme la Bretagne, elle pourrait avoir beaucoup plus d'importance (Feuga, 2010).

Cette thèse contribue à la compréhension des processus d'adoption des systèmes de culture pérennes en situation d'incertitude. Nous montrons que l'aversion au risque peut paradoxalement avoir un effet positif sur l'adoption lorsque des contrats de production adaptés sont proposés. De plus, nos résultats illustrent la complexité des relations entre préférences par rapport au risque et adoption lorsque la dépendance au point de référence et la déformation des probabilités sont envisagées, en même temps que les différences de rentabilité en fonction du type de terre. Notre analyse est facilement généralisable à l'ensemble des cultures pérennes car elle est basée sur des caractéristiques qui leur sont communes : résilience en conditions pédo-climatiques défavorables, conduite extensive et existence d'événements extrêmement défavorables comme l'échec de l'implantation (Glover et al., 2010; Byrne et al., 2010; Bathgate and Pannell, 2002).

Notre travail a également des implications importantes pour la conception de dispositifs encourageant le développement de l'offre de biomasse-énergie. Il suggère qu'un prix garanti à long terme et des facilités de financement des frais d'implantation sont nécessaires pour que les volumes nécessaires au développement des filières de biocarburants de deuxième génération soient atteints. Une attention particulière doit aussi être portée au partage des risques extrêmes.

Cette thèse contribue enfin au débat sur la durabilité des filières de biocarburants de deuxième génération. Les agriculteurs ayant intérêt économiquement à cultiver les espèces pérennes sur des terres marginales, que ce soit en termes de rentabilité ou de risque, les unités de tranformation devraient être localisées de préférences dans des régions où les exploitations présentent des parcellaires hétérogènes. Les actions de promotion et démonstration devraient viser en priorité des conditions de culture marginales.

Il existe de multiples manières d'approfondir et de prolonger nos recherches. Sur la question du lien entre préférences individuelles et adoption, il nous semble par exemple pertinent d'envisager le rôle de l'aversion à l'ambigüïté. En effet, le manque de connaissances des agriculteurs à propos des innovations les rend particulièrement *ambiguës* à leurs yeux, au sens où ils ne sont pas capables de donner une distribution de probabilités explicite pour les revenus attendus. Au cours de notre expérience en Bourgogne, nous avons mesuré l'aversion à l'ambigüïté des agriculteurs mais nous n'avons pas encore pu analyser les résultats. Par ailleurs, dans cette thèse, nous nous sommes concentrée sur des cadres théoriques statiques alors que les cultures pérennes appellent par définition à une analyse dynamique. Le cadre des préférences récursives d'Epstein and Zin (1989) permettrait de séparer aversion au risque et aversion aux fluctuations intertemporelles. L'application de modèles dépendant du signe comme la théorie des perspectives à des choix dynamiques permettrait, elle, de prendre en compte un point de référence non stationnaire. Les revenus obtenus à une période donnée seraient classifiés en gains ou pertes en fonction des revenus obtenus à la période précédente.

Sur la question de l'offre de biomasse-énergie par les agriculteurs et des moyens de l'augmenter à un coût raisonnable, tester différentes formes de contrats de production dans des expérience de choix [46] est une voie de recherche prometteuse. Nos résultats montrent que dans ces expériences il serait judicieux de prendre en compte différents types de terre car l'effet des contrats en dépendra probablement. Il serait aussi important d'associer ces expériences à une évaluation

46. *Choice experiments* en anglais.

rigoureuse des distributions de revenus perçues par les agriculteurs, en se concentrant sur la représentation des points de référence et des événements extrêmes. Il faudrait aussi aller plus loin dans la définition des terres marginales en distinguant celles avec un effet sur les probabilités de revenus (qualité de sol essentiellement) et celles avec un effet sur les moyennes de revenus (parcelles à géométrie particulière ou éloignées).

Sur la question de la durabilité des biocarburants de deuxième génération, une meilleure évaluation des conséquences environnementales des choix d'adoption est cruciale pour l'arbitrage entre volume et durabilité de la production de biomasse-énergie. Pour cela, une caractérisation plus fine des choix de localisation en fonction des parcellaires (géométrie, qualité de sols, éloignement, usage) apparaît nécessaire. Une approche spatiale est plus que recommandée pour traiter correctement des effets des biocarburants de deuxième génération sur les émissions de gaz à effet de serre et la production alimentaire.

Annexes

Appendix A

Detailed variable costs of crops

Table A.1: Variable costs of perennial energy crops according to time period

Cost item	Annual costs (€/ha/yr)									
	Switchgrass					Miscanthus				
	1	2	3	4 to T-1	T	1	2	3	4 to T-1	T
Operating costs	695	268	221	261	428	3730	55	219	282	434
Seeds/Rhizomes	600					2800				
Fertilizer	40			40		75			55	
Herbicide	55	55				55	55			
Planting (contractor)					800					
Harvest (contractor)		200	200	200	200			200	200	200
Plastic sheeting for storage[a]		13	21	21	21			19	27	27
Uprooting (contractor)					207					207
Machinery costs	64	19	16	18	16	58	9	14	22	20
Fuel/lube	28	13	16	17	16	26	3	14	21	20
Repairs	36	6	0	1	0	32	6	0	1	0
Labour costs	34	12	12	13	12	31	5	11	17	16

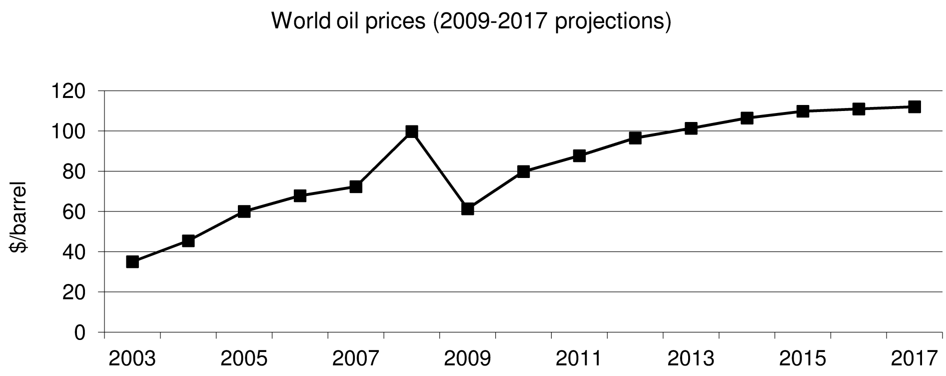
[a] 1.6 €/dry ton

Table A.2: Variable costs of traditional crops

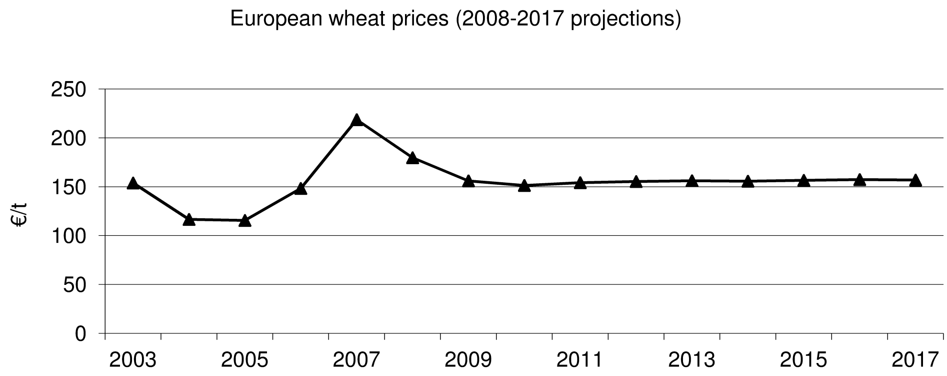
Cost item	Annual costs (€/ha/yr)		
	Rape	Soft wheat	Winter barley
Operational costs	271	347	320
Seeds	28	55	55
Fertilizer	80	90	80
Other chemicals	63	107	95
Harvest (contractor)	100	95	90
Machinery costs	78	89	88
Fuel/lube	40	45	45
Repairs	38	44	43
Labour costs	37	44	44

Appendix B

Price projections



Source: Annual Energy Outlook 2009, DOE/EIA 2009, available at: http://www.eia.gov/oiaf/archive/aeo09/.



Source: OECD-FAO Agricultural Outlook 2008-2017, OECD/FAO 2008, database available at: http://stats.oecd.org/index.aspx.

Figure B.1: Oil and wheat price projections.

Appendix C

Instructions (risk task only)

The experiment in which you are going to take part is part of a multidisciplinary **research project** involving more than 30 researchers from 4 different institutes. Specifically, this experiment relates to a Ph.D. thesis in Economic Sciences being carried out at the French National Institute for Agricultural Research (INRA).

Please answer successively **several questions grouped into three different tasks**. In these tasks, we stylized situations of financial risk or trade-off between present and future. The former are lottery games. These schemes are used in economic research to make people reveal their preferences for choices more or less risky or more or less delayed.

All the questions correspond to fictional situations, but we kindly ask you to answer as if **you were faced with a real situation**, taking the necessary time to make the choices that match your preferences best. Before each task, one or several examples will be given. Tasks are independent.

After the experiment is finished, one task will be selected at random, and then one question of the selected task. You will receive a **real payment** which will depend on the choice you made. Unfortunately, we are not able to offer the full amount at stake, therefore we will provide a certain percentage of the original stakes. **This percentage, fixed in advanced, will be revealed to you after you had completed the whole experiment.** It is indicated in this envelope which we place in front of you. In practical terms, if the selected question is a lottery choice, the lottery you have chosen is played and the discounting percentage is applied to the winning stake. If the selected question corresponds to a time of payment choice, the timing you have chosen gives the time of the payment and the discounting percentage is applied to the corresponding stake.

As some tasks can involve gains or losses, **we are give now giving you a fixed endowment of 15 euros**. The gain or the loss you will earn in the experiment will be added to this initial amount. We will ask you to sign a receipt for the final earnings. The payment procedure was conceived so that **you will receive a positive final amount**, whatever your responses.

If the payment is due on a future date (3 years maximum), we will provide you an official IOU from the financing organism (ADEPRINA). You will spontaneously receive by mail a cheque on the due date. The researchers involved in the experiment will make sure that payment dates are respected.

For statistical needs, it is important that you answer all the questions. Your responses will be treated anonymously and will be kept confidential. Results will be presented in scientific publications in an aggregated form and, as such, will respect anonymity.

Thank you for your collaboration in this research!

TASK 1 : RISK

This task is composed of 3 series, and totals 33 choice questions: 12 in series 1, 14 in series 2, and 7 in series 3. Each question corresponds to a choice between a lottery A and a lottery B, where gains and losses are both possible, each stake corresponding to a probability of occurrence. At the beginning of the experiment, no one knows the outcome of the lotteries. Lotteries will be played by pulling a ball out of an urn containing orange and white balls. The proportion of orange and white balls will represent the probabilities associated with the lottery selected for the payment.

For each question, you will choose the lottery you prefer.

At the end of the experiment, if task 1 is selected at random for the real payment, 33 balls with numbers 1 to 33 will be placed in the urn, and you will draw one. The question selected for the payment will be the question corresponding to the ball drawn. For instance, if you draw ball number 4, we will play the lottery (A or B) chosen in question number 4 (thanks to the orange and white balls).

Example

As an example, let's consider a series of 5 questions, whose design corresponds to series 1 and 2 of the risk task.

	Urn A (3 ORANGE + 7 WHITE)		Urn B (1 ORANGE + 9 WHITE)	
Question	Option A		Option B	
1	200 €	(if the ball drawn is orange, i.e., a 30% chance)	350 €	(if the ball drawn is orange, i.e., a 10% chance)
	or 100 €	(if the ball drawn is white, i.e., a 70% chance)	or 60 €	(if the ball drawn is white, i.e., a 90% chance)
2	200 €	(orange)	400 €	(orange)
	or 100 €	(white)	or 60 €	(white)
3	200 €	(orange)	450 €	(orange)
	or 100 €	(white)	or 60 €	(white)
4	200 €	(orange)	500 €	(orange)
	or 100 €	(white)	or 60 €	(white)
5	200 €	(orange)	550 €	(orange)
	or 100 €	(white)	or 60 €	(white)

Answer :
– I choose lottery A for questions 1 to 3.

– I choose lottery B for questions 4 to 5.

You must choose between lottery A and lottery B for each question. Let's assume that you choose lottery A for questions 1 to 3, and lottery B for questions 4 to 5. Thus, you must indicate in the boxes at the bottom of the table the numbers 3 and 4.

Let's now assume that by chance question 4 is selected for payment. In this question, you chose lottery B. Thus, we put 1 orange ball and 9 white balls into the urn to represent the probabilities of the amounts at stake in lottery B. You play the lottery by drawing 1 ball out of the 10 in the urn.
– If the ball drawn is orange, you earn a percentage of 500€.
– If the ball drawn is white, you earn the same percentage of only 60€.

Other example

Let's now consider a new series of 5 questions, whose design corresponds to series 3 of the risk task. In this series, you may loose money (negative stakes).

	Urn A (5 ORANGE + 5 WHITE)		Urn B (5 ORANGE + 5 WHITE)	
Question	Option A		Option B	
6	200 € or -300 €	(if the ball drawn is orange, i.e., a 50% chance) (if the ball drawn is white, i.e., a 50% chance)	300 € or -350 €	(if the ball drawn is orange, i.e., a 50% chance) (if the ball drawn is white, i.e., a 50% chance)
7	180 € or -300 €	(orange) (white)	300 € or -350 €	(orange) (white)
8	160 € or -300 €	(orange) (white)	300 € or -350 €	(orange) (white)
9	120 € or -300 €	(orange) (white)	300 € or -350 €	(orange) (white)
10	100 € or -300 €	(orange) (white)	300 € or -350 €	(orange) (white)

Answer :
– I choose lottery A for questions 6 to XX.

– I choose lottery B for questions 6 to 10.

Again, you are asked to choose between lottery A and lottery B for each question. Let's assume that you never choose lottery A, but lottery B for all questions (it could also be the opposite). Thus, you must ignore the first answer item at the bottom of the table and indicate number 6 in the box of the second item.

Let's now assume that by chance question 6 is selected for payment. In this question, you chose lottery B. Thus, we put 5 orange ball and 5 white balls into the urn to represent the probabilities of lottery B, orange balls for gains and white balls for losses. You play the lottery by drawing 1 ball out of the 10 in the urn.

- If the ball drawn is orange, you earn a percentage of 300€.
- If the ball drawn is white, you loose the same percentage of 350€. This amount is subtracted from your initial endowment of 15€.

If you do not have questions, we can now begin the risk task.

Appendix D

Record sheets (risk task only)

RISK TASK. Series 1.

Answer :

– I choose lottery A for questions 1 to ☐.

– I choose lottery B for questions ☐ to 12.

	Urn A (3 ORANGE + 7 BLANCHES)		Urn B (1 ORANGE + 9 BLANCHES)	
Question	Option A		Option B	
1	400 € or 100 €	(if the ball drawn is orange, soit 30% chance) (if the ball drawn is white, i.e., a 70% chance)	680 € or 50 €	(if the ball drawn is orange, i.e., a 10% chance) (if the ball drawn is white, i.e., a 90% chance)
2	400 € or 100 €	(orange) (white)	750 € or 50 €	(orange) (white)
3	400 € or 100 €	(orange) (white)	830 € or 50 €	(orange) (white)
4	400 € or 100 €	(orange) (white)	930 € or 50 €	(orange) (white)
5	400 € or 100 €	(orange) (white)	1065 € or 50 €	(orange) (white)
6	400 € or 100 €	(orange) (white)	1250 € or 50 €	(orange) (white)
7	400 € or 100 €	(orange) (white)	1500 € or 50 €	(orange) (white)
8	400 € or 100 €	(orange) (white)	1850 € or 50 €	(orange) (white)
9	400 € or 100 €	(orange) (white)	2200 € or 50 €	(orange) (white)
10	400 € or 100 €	(orange) (white)	3000 € or 50 €	(orange) (white)
11	400 € or 100 €	(orange) (white)	4000 € or 50 €	(orange) (white)
12	400 € or 100 €	(orange) (white)	6000 € or 50 €	(orange) (white)

RISK TASK. Series 2.

Answer :

– I choose lottery A for questions 13 to ☐.

– I choose lottery B for questions ☐ to 26.

	Urne A (9 ORANGE + 1 WHITE)		Urne B (7 ORANGE + 3 WHITE)	
Question	Option A		Option B	
13	400 €	(if the ball drawn is orange, soit 90% chance)	540 €	(if the ball drawn is orange, i.e., a 70% chance)
	or 300 €	(if the ball drawn is white, i.e., a 10% chance)	or 50 €	(if the ball drawn is white, i.e., a 30% chance)
14	400 €	(orange)	560 €	(orange)
	or 300 €	(white)	or 50 €	(white)
15	400 €	(orange)	580 €	(orange)
	or 300 €	(white)	or 50 €	(white)
16	400 €	(orange)	600 €	(orange)
	or 300 €	(white)	or 50 €	(white)
17	400 €	(orange)	620 €	(orange)
	or 300 €	(white)	or 50 €	(white)
18	400 €	(orange)	650 €	(orange)
	or 300 €	(white)	or 50 €	(white)
19	400 €	(orange)	680 €	(orange)
	or 300 €	(white)	or 50 €	(white)
20	400 €	(orange)	720 €	(orange)
	or 300 €	(white)	or 50 €	(white)
21	400 €	(orange)	770 €	(orange)
	or 300 €	(white)	or 50 €	(white)
22	400 €	(orange)	830 €	(orange)
	or 300 €	(white)	or 50 €	(white)
23	400 €	(orange)	900 €	(orange)
	or 300 €	(white)	or 50 €	(white)
24	400 €	(orange)	1000 €	(orange)
	or 300 €	(white)	or 50 €	(white)
25	400 €	(orange)	1100 €	(orange)
	or 300 €	(white)	or 50 €	(white)
26	400 €	(orange)	1300 €	(orange)
	or 300 €	(white)	or 50 €	(white)

RISK TASK. Series 3.

Answer :

– I choose lottery A for questions 27 to ☐.

– I choose lottery B for questions ☐ to 33.

	Urn A (5 ORANGE + 5 WHITE)		Urn B (5 ORANGE + 5 WHITE)	
Question	Option A		Option B	
27	250 €	(if the ball drawn is orange, soit 50% chance)	300 €	(if the ball drawn is orange, i.e., a 50% chance)
	or -40 €	(if the ball drawn is white, i.e., a 50% chance)	or -210 €	(if the ball drawn is white, i.e., a 50% chance)
28	40 €	(orange)	300 €	(orange)
	or -40 €	(white)	or -210 €	(white)
29	10 €	(orange)	300 €	(orange)
	or -40 €	(white)	or -210 €	(white)
30	10 €	(orange)	300 €	(orange)
	or -40 €	(white)	or -160 €	(white)
31	10 €	(orange)	300 €	(orange)
	or -80 €	(white)	or -160 €	(white)
32	10 €	(orange)	300 €	(orange)
	or -80 €	(white)	or -140 €	(white)
33	10 €	(orange)	300 €	(orange)
	or -80 €	(white)	or -110 €	(white)

Appendix E

Robustness checks

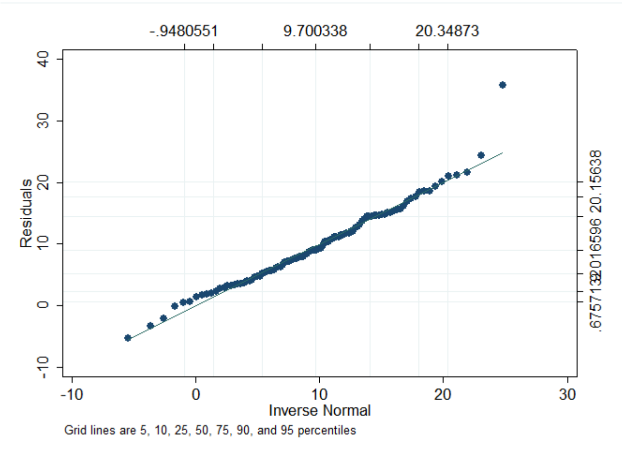


Figure E.1: Quantile-Quantile plot of the Tobit residuals (model T) against the inverse normal distribution

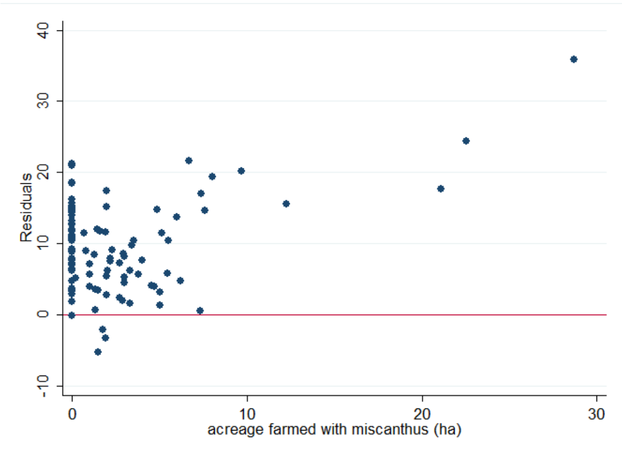


Figure E.2: Scatter plot of the Tobit residuals (model T) against the dependent variable

Table E.1: Variance inflation factor of base explanatory variables

	VIF
Farmer characteristics	
Age	2.096
ExtraInc	1.571
PublicInfo	1.396
PrivateInfo	1.248
Farm characteristics	
FarmSize	1.488
LandOwned	1.792
Livestock	1.489
ExBeet	1.443
Margin	1.297
Wood	1.618
North	1.440
WheatRisk	1.606
Individual preferences	
EnvironObjFirst	1.729
VConcavity	1.467
LossAversion	1.702
WeightExtreme	1.489
StdDiscount	5.414
PresentBias	5.006

VIF are computed manually in order to account for our survey design.

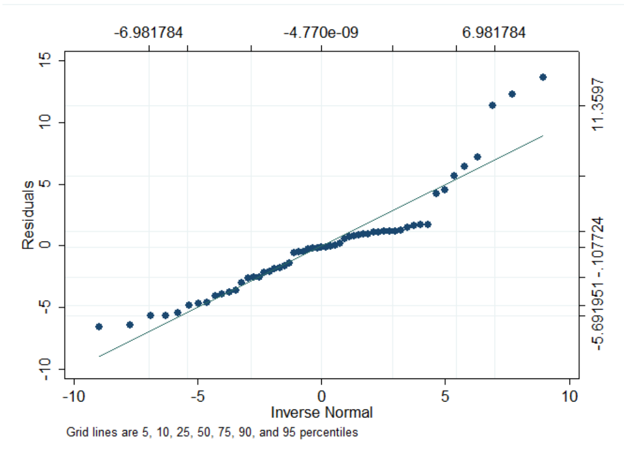


Figure E.3: Quantile-Quantile plot of the two-part-model residuals (intensity equation of model A0) against the inverse normal distribution

Table E.2: Marginal effects on miscanthus adoption for different sub-samples

	Model A5 (random selection)		Model A6 (discarding outliers)	
	Pr(Adopter=1)	E(MiscAcreage|Adopter=1)	Pr(Adopter=1)	E(MiscAcreage|Adopter=1)
Farmer characteristics				
Age	−0.006**	−0.040	−0.006*	−0.036
	(0.003)	(0.042)	(0.004)	(0.029)
ExtraInc	0.114	2.253	0.147	−0.387
	(0.088)	(1.691)	(0.127)	(1.163)
PublicInfo	0.015	0.140	0.016	0.120
	(0.012)	(0.252)	(0.018)	(0.173)
PrivateInfo	−0.019	−0.340	−0.009	−0.154
	(0.014)	(0.278)	(0.020)	(0.180)
Farm characteristics				
FarmSize	0.117***	−0.191	0.102***	−0.546**
	(0.023)	(0.476)	(0.030)	(0.270)
LandOwned	−0.283**	−1.328	−0.196	−0.065
	(0.121)	(1.867)	(0.166)	(1.658)
1.Livestock	−0.149***	−1.090	−0.128**	0.229
	(0.028)	(0.876)	(0.049)	(0.597)
1.ExBeet	0.105**	0.707	0.124	0.130
	(0.046)	(1.094)	(0.075)	(0.850)
1.Margin	0.193***	0.703	0.138**	−0.414
	(0.030)	(2.283)	(0.054)	(1.167)
1.Wood	0.078	0.791	0.081	−0.123
	(0.050)	(0.972)	(0.071)	(0.765)
1.North	−0.027	0.261	−0.007	−0.039
	(0.049)	(1.359)	(0.070)	(0.940)
WheatRisk	0.024	−0.672	0.001	−1.144**
	(0.037)	(0.618)	(0.051)	(0.509)
Individual preferences				
1.EnvironObjFirst	0.102	−1.032	0.197	−0.017
	(0.169)	(1.158)	(0.188)	(0.879)
VConcavity	0.003	1.029	0.029	1.023
	(0.055)	(1.018)	(0.066)	(0.762)
LossAversion	−0.002	0.290*	0.000	0.045
	(0.008)	(0.165)	(0.011)	(0.108)
WeightExtreme	−0.171***	−0.827	−0.160*	1.170
	(0.066)	(1.317)	(0.083)	(1.118)
StdDiscount	−0.647	−11.827	−0.330	−9.412*
	(0.544)	(7.396)	(0.735)	(5.417)
PresentBias	−0.381	−3.660	−0.379	−3.652
	(0.379)	(5.095)	(0.472)	(3.933)
Nb. of observations	307	49	99	54
Model p-value	0.00	0.57	0.08	0.61
Prop. correctly predicted	0.88		0.87	
Prop. variance explained		0.30		0.28

*, ** and *** stand for significance at the 10, 5 and 1% level, respectively. The marginal effects are evaluated at the observed values in the dataset and then averaged (average marginal effects). For binary variables, they are computed as the effect of a discrete change from 0 to 1. The standard errors (in parentheses) are adjusted for our survey design. In the case of the intensity equation, we report the marginal effects on the expected values for the outcome conditional on being positive.
Model 6 is estimated on a random subsample discarding 20% of the observations.
Model 7 is estimated on a subsample where farmers growing 20 ha or more of miscanthus were discarded.

Table E.3: Marginal effects on miscanthus adoption according to type of land for different sub-samples

	Model L5 (random selection)		Model L6 (discarding outliers)	
	Pr(MarginUsed=1)	Pr(PlainUsed=1)	Pr(MarginUsed=1)	Pr(PlainUsed=1)
Farmer characteristics				
Age	−0.004*	−0.004*	−0.006*	−0.004*
	(0.002)	(0.002)	(0.003)	(0.002)
ExtraInc	0.163**	0.100	0.178*	0.027
	(0.075)	(0.067)	(0.101)	(0.080)
PublicInfo	0.023**	−0.004	0.018	−0.010
	(0.011)	(0.011)	(0.015)	(0.011)
PrivateInfo	−0.015	0.007	−0.016	−0.001
	(0.011)	(0.011)	(0.016)	(0.011)
Farm characteristics				
FarmSize	0.057***	0.054***	0.061***	0.054***
	(0.017)	(0.017)	(0.022)	(0.018)
LandOwned	−0.091	−0.145	−0.047	−0.128
	(0.088)	(0.091)	(0.123)	(0.121)
1.Livestock	−0.083***	−0.071**	−0.094**	−0.050
	(0.031)	(0.031)	(0.038)	(0.039)
1.ExBeet	0.016	0.092**	0.044	0.135**
	(0.038)	(0.045)	(0.056)	(0.065)
1.Margin	.	−0.016	.	0.025
		(0.048)		(0.046)
1.Wood	0.066	0.120**	0.070	0.061
	(0.054)	(0.052)	(0.061)	(0.051)
1.North	−0.028	−0.010	−0.012	0.062
	(0.039)	(0.043)	(0.055)	(0.060)
WheatRisk	−0.008	0.010	−0.005	0.025
	(0.030)	(0.029)	(0.040)	(0.031)
Individual preferences				
1.EnvironObjFirst	0.056	0.080	0.052	0.056
	(0.102)	(0.113)	(0.119)	(0.119)
VConcavity	0.087*	0.006	0.084	−0.026
	(0.051)	(0.040)	(0.062)	(0.039)
LossAversion	0.003	−0.002	0.005	0.000
	(0.006)	(0.006)	(0.008)	(0.006)
WeightExtreme	−0.059	−0.113**	−0.079	−0.092*
	(0.050)	(0.055)	(0.066)	(0.052)
StdDiscount	−1.058**	0.588	−0.965*	0.446
	(0.447)	(0.417)	(0.535)	(0.420)
PresentBias	−0.488	0.168	−0.522	−0.114
	(0.328)	(0.297)	(0.360)	(0.289)
ρ				
Nb. of observations	307	307	99	99
Model p-value	0.01	.	0.03	.
P. c. p. (any land)	0.98		0.86	
P. c. p. (marginal land)	0.98		0.87	
P. c. p. (plain land)		0.99		0.91

*, ** and *** stand for significance at the 10, 5 and 1% level, respectively. The marginal effects are evaluated at the observed values in the dataset and then averaged (average marginal effects). For binary variables, they are computed as the effect of a discrete change from 0 to 1. The standard errors (in parentheses) are adjusted for our survey design.
Model L6 is estimated on a random subsample discarding 20% of the observations.
Model L7 is estimated on a subsample where farmers growing 20 ha or more of miscanthus were discarded.

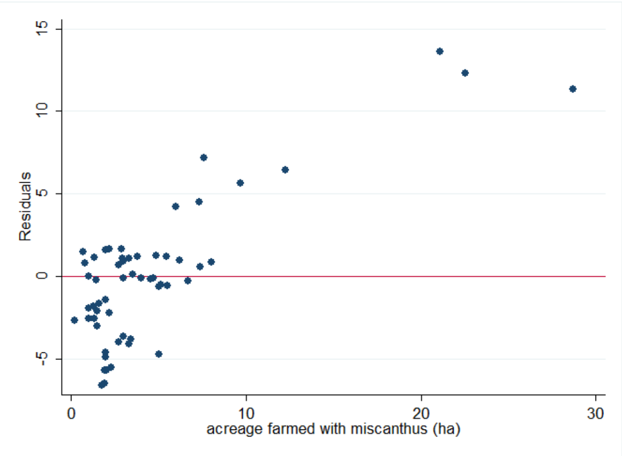


Figure E.4: Scatter plot of the two-part-model residuals (intensity equation of model A0) against the dependent variable

Appendix F

Questionnaire

Analyse des déterminants de l'adoption des cultures pérennes énergétiques

Principe de l'enquête

Le questionnaire auquel vous allez répondre est destiné à mieux comprendre les raisons pour lesquelles vous avez décidé (ou pourriez décider) de cultiver des cultures pérennes énergétiques, ou au contraire de ne pas en cultiver. Il s'agit d'une question importante pour juger de la pertinence de ces cultures comme source d'énergie renouvelable, et évaluer les volumes qui seront disponibles demain.

Vous serez peut-être surpris du nombre de questions ayant trait à votre activité agricole en général, sans référence particulière aux cultures énergétiques. Il s'agit en fait pour nous d'identifier de manière objective les éléments discriminants dans la prise de décision entre les différents chefs d'exploitation que nous rencontrons. Certains renseignements techniques et économiques nous permettrons aussi de construire un modèle général d'exploitation, et de vérifier qu'il est capable de reproduire des situations réelles.

Pour les besoins de l'analyse statistique il est important de répondre à toutes les questions. Vos réponses seront traitées de façon anonyme et resteront tout à fait confidentielles. Les résultats seront présentés sous forme agrégée dans des publications scientifiques et respecteront donc scrupuleusement l'anonymat des réponses.

Un grand merci pour votre collaboration à la réussite de ce travail !

Questionnaire

Le questionnaire comprend 4 parties. La première vise à identifier les facteurs influençant votre décision de cultiver ou non des cultures pérennes énergétiques. La deuxième comporte des questions spécifiques sur les cultures pérennes énergétiques. La troisième partie est destinée à collecter les caractéristiques de votre environnement social et économique, ainsi que des données socio-démographiques vous concernant. La dernière nous permettra d'évaluer vos perceptions et anticipations sur un certain nombre de questions.

Sauf indication contraire, les informations demandées se rapportent à la campagne agricole 2009/2010 ou à l'année civile 2009.

Cocher la (les) cas(s) correspondant à votre (vos) réponse(s), ou bien remplissez le champ prévu.

Nom	Prénom	
Adresse du siège de l'exploitation	Code Postal	Commune
Numéro de téléphone	Mail	

Code région	Numéro de pacage
Coordonnées SIG du siège de l'exploitation	
Distance de l'exploitation à l'usine km	

Date enquête / /2010	Code enquêteur

Nous commençons par quelques questions générales pour connaître votre exploitation dans les grandes lignes, et nous reviendrons en fin de questionnaire sur les détails.

1. Sexe décideur ☐ F ☐ M

2. Organisation juridique et associés

☐ exploitant individuel

☐ EARL : Associé 1 : Part : %
Associé 2 : Part : %
Associé 3 : Part : %

☐ GAEC : Associé 1 : Part : %
Associé 2 : Part : %
Associé 3 : Part : %

☐ Autre forme sociétaire (SCEA…) : Associé 1 : Part : %
Associé 2 : Part : %
Associé 3 : Part : %

3. Surfaces

TOTAL SAU : ha, dont :
-superficie céréales et oléoprotéagineux (yc lin et chanvre, hors gel) (SCOP) ha
-superficie toujours en herbe (STH) ha
-superficie fourragère principale (SFP) ha
-superficies gelées (environnemental+industriel+faune sauvage…)
2008/2009 ha
2007/2008 ha

-SAU en faire-valoir direct ha
-SAU en zone vulnérable ha

TOTAL HORS SAU : ha, dont :
-superficie boisée ha

En moyenne, quelle surface est irriguée au moins une fois chaque année ? ha

4. Activité principale

- ☐ Céréales et oléoprotéagineux
- ☐ Cultures générales (betterave, légumes, pomme de terre…)
- ☐ Bovins élevage et viande
- ☐ Grandes cultures et herbivores de manière équivalente
- ☐ Vins d'appellation d'origine
- ☐ Autres :

PARTIE 1

5. **Combien d'îlots (au sens PAC) possédez-vous, et quelle est la surface de chacun ?**
   îlots : îlot 1 : ha, îlot 2 : ha, îlot 3 : ha (…)

6. **Estimez-vous que certaines de vos parcelles sont particulièrement difficiles à travailler par rapport au reste de votre exploitation, à cause de coûts élevés (yc en travail), de rendements faibles ou d'autres contraintes ?**

☐ OUI ☐ NON

Lesquelles ? Indiquez les îlots concernés sur les photos aériennes de votre exploitation.
Selon quels critères ? Quelle en est l'utilisation ?

N° îlot	*Surf.*	*Critère 1*	*Critère 2*	*Critère 3*	*Critère 4*	*Utilisation*	*Type de sol*	*Distance (km)*	*Pente (%)*
	ha	☐ qualité ☐ éloignt ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ qualité ☐ éloignt ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ qualité ☐ éloignt ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ qualité ☐ éloignt ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ rotation de cultures : ☐ prairie permanente productive ☐ gel permanent ☐ autre :			
	ha	☐ qualité ☐ éloignt ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ qualité ☐ éloignt ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ qualité ☐ éloignt ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ qualité ☐ éloignt ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ rotation de cultures : ☐ prairie permanente productive ☐ gel permanent ☐ autre :			
	ha	☐ qualité ☐ éloignt ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ qualité ☐ éloignt ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ qualité ☐ éloignt ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ qualité ☐ éloignt ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ rotation de cultures : ☐ prairie permanente productive ☐ gel permanent ☐ autre :			
	ha	☐ qualité ☐ éloignt ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ qualité ☐ éloignt ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ qualité ☐ éloignt ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ qualité ☐ éloignt ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ rotation de cultures : ☐ prairie permanente productive ☐ gel permanent ☐ autre :			

	ha	☐ qualité ☐ éloign^{t} ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ qualité ☐ éloign^{t} ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ qualité ☐ éloign^{t} ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ qualité ☐ éloign^{t} ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ rotation de cultures : ☐ prairie permanente productive ☐ gel permanent ☐ autre :			
	ha	☐ qualité ☐ éloign^{t} ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ qualité ☐ éloign^{t} ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ qualité ☐ éloign^{t} ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ qualité ☐ éloign^{t} ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ rotation de cultures : ☐ prairie permanente productive ☐ gel permanent ☐ autre :			
	ha	☐ qualité ☐ éloign^{t} ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ qualité ☐ éloign^{t} ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ qualité ☐ éloign^{t} ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ qualité ☐ éloign^{t} ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ rotation de cultures : ☐ prairie permanente productive ☐ gel permanent ☐ autre :			
	ha	☐ qualité ☐ éloign^{t} ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ qualité ☐ éloign^{t} ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ qualité ☐ éloign^{t} ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ qualité ☐ éloign^{t} ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ rotation de cultures : ☐ prairie permanente productive ☐ gel permanent ☐ autre :			
	ha	☐ qualité ☐ éloign^{t} ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ qualité ☐ éloign^{t} ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ qualité ☐ éloign^{t} ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ qualité ☐ éloign^{t} ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ rotation de cultures : ☐ prairie permanente productive ☐ gel permanent ☐ autre :			
...									

Où se situe en moyenne votre exploitation par rapport à ces 5 critères ?

Critère 1 : répartition de la SAU en fonction du type de terre

% SOL 1 : - granulométrie : % limons, % argiles, % sables
- taux de cailloux : %
- profondeur du sol : cm
- cultures exclues et pourquoi :
  - ☐ aucune
  - ☐ culture 1 : ,
  - ☐ culture 2 : ,
  - ☐ culture 3 : ,

% SOL 2 : - granulométrie : % limons, % argiles, % sables
- taux de cailloux : %
- profondeur du sol : cm
- cultures exclues et pourquoi :
  - ☐ aucune
  - ☐ culture 1 : ,
  - ☐ culture 2 : ,
  - ☐ culture 3 : ,

% SOL 3 : - granulométrie : % limons, % argiles, % sables
- taux de cailloux : %
- profondeur du sol : cm
- cultures exclues et pourquoi :
  - ☐ aucune
  - ☐ culture 1 : ,
  - ☐ culture 2 : ,
  - ☐ culture 3 : ,

% SOL 4 : - granulométrie : % limons, % argiles, % sables
- taux de cailloux : %
- profondeur du sol : cm
- cultures exclues et pourquoi :
  - ☐ aucune
  - ☐ culture 1 : ,
  - ☐ culture 2 : ,
  - ☐ culture 3 : ,

Critère 3 : répartition des îlots en fonction de la distance de l'accès de l'îlot au siège de l'exploitation

ha à moins de 1 km
ha de 1 à 5 km
ha à plus de 5km et moins de 10 km
ha à plus de 10km

Critère 4 : répartition des îlots en fonction de leur pente

ha sans pente
ha avec moins de 5% de pente
ha entre 5 et 10% de pente
ha de plus de 10% de pente

Critère 5 : répartition des îlots en fonction de leur forme (nombre d'angles et périmètre)
Fait ex post avec les photos RPG du parcellaire (avec Google Earth).

îlot 1 : angles et m de périmètre
îlot 2 : angles et m de périmètre
îlot 3 : angles et m de périmètre
îlot 4 : angles et m de périmètre
îlot 5 : angles et m de périmètre
îlot 6 : angles et m de périmètre
îlot 7 : angles et m de périmètre

Critère 2 : répartition des îlots en fonction de leur taille
Fait ex post avec les photos RPG du parcellaire (avec Google Earth).

îlots de moins de 1ha
îlots entre 1 et 5ha
îlots entre 5 et 10ha
îlots de plus de 10ha

7. Sur vos parcelles en <u>blé tendre</u>, de manière générale :

- quand commencez-vous les semis ?
- quand les terminez-vous ?

- préférez-vous des variétés rustiques résistantes aux maladies ☐ ou des variétés à haut potentiel de rendement sensibles aux maladies ☐ ou une combinaison des 2 ☐?

- quels sont vos critères de choix pour les variétés (numéroter de 1 à 5 du plus important au moins important) ?

☐ tolérance aux maladies ☐ rendement
☐ précocité ☐ autres :

- combien de passages de fongicides réalisez-vous ? entre et passages par an ou plutôt passages par an voire

- appliquez-vous le même programme fongicide à toutes les parcelles ? ☐ OUI ☐NON
si non, quel est le facteur de modification ?

- quelle dose d'azote appliquez-vous ? uN/ha
- en combien de passages ? passages
- appliquez-vous un régulateur de croissance ? ☐ OUI ☐NON
- réalisez-vous un désherbage mécanique ? ☐ OUI ☐NON

- quel intervalle (effet climat hors années trop extrêmes comme la canicule de 2003+effet maladies) et moyenne de rendement obtenez-vous ?

qx/ha à qx/ha, avec une moyenne de qx/ha sur le sol
qx/ha à qx/ha, avec une moyenne de qx/ha sur le sol
qx/ha à qx/ha, avec une moyenne de qx/ha sur le sol
qx/ha à qx/ha, avec une moyenne de qx/ha sur le sol

8. **Pratiquez-vous l'agriculture biologique ?**
☐ OUI, certification obtenue
☐ OUI, en conversion
☐ NON

Votre exploitation est-elle qualifiée agriculture raisonnée (FARRE, etc…) ?
☐ OUI, qualification obtenue
☐ OUI, en conversion
☐ NON

9. **A quelles MAE (mesures agri-environnementales) souscrivez-vous, et pour quelle surface ?** ☐ aucune

☐ Prime herbagère agro-environnementale (dispositif A)
sur une surface de ha
☐ Diversification des assolements en cultures arables (dispositif B)
sur une surface de ha
☐ Système fourrager polyculture-élevage économe en intrants (dispositif C)
sur une surface de ha
☐ Conversion à l'agriculture biologique (dispositif D)
sur une surface de ha
☐ Maintien de l'agriculture biologique (dispositif E)
sur une surface de ha
☐ Protection des races menacées (dispositif F)
☐ Préservation des ressources végétales menacées de disparition (dispositif G)
☐ Apiculture (dispositif H) Nombre de ruches :
☐ Mesures territorialisées (dispositif I) :
- ☐ Parc du Morvan : ha
- ☐ Natura 2000 vallée de Rhoin : ha
- ☐ Natura 2000 Arrière côte Dijon et Beaune : ha
- ☐ BAC Chevannes : ha
- ☐ bassin versant de : ha
- ☐ bassin versant de : ha
- ☐ bassin versant de : ha
- ☐ Natura 2000 Beauce-vallée de la Conie : ha

10. **Pratiquez-vous ou avez-vous pratiqué le semis direct** (au sens de : jamais de labour sur une parcelle donnée) **?** ☐ OUI ☐NON

Quelle année l'avez-vous pratiqué pour la première fois ?

11. Pratiquez-vous ou avez-vous pratiqué les TCS ? ☐ OUI ☐ NON
Quelle année l'avez-vous pratiqué pour la première fois ?

12. Au cours des dix dernières années, avez-vous introduit une ou plusieurs cultures nouvelles dans votre assolement ? ☐ OUI ☐ NON
Si oui, laquelle (lesquelles), en quelle année et pourquoi?
culture 1 : , en car
culture 2 : , en car
culture 3 : , en car
culture 4 : , en car
culture 5 : , en car
culture 6 : , en car

En particulier, avez- vous introduit le pois protéagineux récemment (ou un autre protéagineux) ? ☐ OUI ☐ NON
Si oui, pourquoi ?

Si non, pourquoi ?
☐ aide supplémentaire de 150€/ha non connue
☐ problème de maladie (aphanomyces p. ex.)
☐ autres :

13. Qu'est-ce qui a remplacé la betterave ? ☐ sans objet
- dans la rotation ?
- économiquement ?

Avez-vous hésité avec une autre culture? ☐ OUI ☐ NON
Si oui, laquelle ?
Pourquoi ?
Si non, pourquoi ?

14. Enfouissez-vous des légumineuses à des fins de fertilisation (trèfle incarnat, …) ?
☐ OUI ☐ NON

15. Certaines de vos parcelles sont-elles soumises à l'obligation d'implanter des CIPAN (cultures intermédiaires pièges à nitrates) ?
☐ OUI (communes classées en zone vulnérable)
☐ OUI (dans le cadre d'une MAE)
☐ NON

En implantez-vous sur des parcelles soumises à aucune obligation ?
☐ sans objet
☐ OUI (uniquement si pratique habituelle)
☐ OUI (recommandation MAE)
☐ NON

16. Avez-vous couramment recours à des techniques d'agriculture de précision ?
☐ OUI ☐NON
Si oui, lesquelles ?

17. Adhérez-vous à un groupe de développement de la Chambre d'Agriculture (Groupe de Vulgarisation Agricole…) ? ☐ OUI ☐NON
Appartenez-vous à un autre groupe de développement (CETA, CIVAM, …) ?
☐ OUI ☐NON
Lequel (lesquels) ?

18. Combien de fois avez-vous déjà participé aux événements suivants au cours des 5 dernières années, en dehors des événements organisés par les groupes mentionnés ci-dessus ?
- salons et manifestations professionnelles fois
(démos en champ, salons Arvalis, Innov-agri, journées Agralys, etc…)
- conférences et sessions de formation spécifiques fois
(Arvalis, Chambres…)

19. Quelles sources d'information technique privilégiez-vous pour prendre vos décisions ? Indiquez 1, 2, 3, 4, ou 5 selon l'importance que vous accordez aux sources d'information suivantes *(1= pas important du tout, 2= peu important, 3= moyennement important, 4= important, 5= très important).*

	Nature des décisions
-journaux agricoles	☐
- d'autres agriculteurs (voisins) :	☐
- bulletins d'information de la Chambre :	☐
- techniciens de la Chambre :	☐
- bulletins d'information de la coopérative ou des négoces :	☐
- techniciens de la coopérative ou des négoces :	☐
- salons et manifestations professionnelles :	☐
- conférences et sessions de formation spécifiques (yc groupe de dvpt)	☐
- internet :	☐
- une autre source d'information :	☐

20. Avez-vous souscrit à une assurance grêle ? ☐ NON
☐ OUI, assurance grêle
Pour quel capital ?
☐ OUI, assurance grêle élargie aux autres aléas climatiques (multi-risques climatiques)
Souscrivez-vous une garantie rendement complémentaire ? ☐ OUI ☐NON
De combien ? t/ha

21. Les prix agricoles sont particulièrement volatils. Lorsqu'il y a des chutes de prix, vous arrive-t-il d'avoir recours à des crédits court terme (crédits de trésorerie) ?
☐ OUI ☐NON

A des différés de paiement (fournisseurs) ?

☐ OUI ☐ NON

Faites-vous des paiements morte saison pour vos intrants ?

☐ OUI ☐ NON

22. **Mettez-vous en concurrence les fournisseurs d'intrants ?** ☐ OUI ☐ NON

23. **A combien d'organismes stockeurs livrez-vous ?**

24. **Pour certaines de vos productions demandant une qualité spéciale, vous pouvez avoir souscrit avec votre (vos) coopérative(s) des « contrats de production », imposant un cahier des charges à respecter.** Indiquez de quelles cultures il s'agit et pour quelles surfaces ou volumes les contrats ont été établis (campagnes 2007/2008 et 2008/2009, hors CPE).

2007/2008					*2008/2009*				
Culture	*Surface (ha)*	*Volume (t)*	*Usage alimentaire ?*	*Durée*	*Culture*	*Surface (ha)*	*Volume (t)*	*Usage alimentaire ?*	*Durée*
			☐ oui ☐ non					☐ oui ☐ non	
			☐ oui ☐ non					☐ oui ☐ non	
			☐ oui ☐ non					☐ oui ☐ non	
			☐ oui ☐ non					☐ oui ☐ non	
			☐ oui ☐ non					☐ oui ☐ non	
			☐ oui ☐ non					☐ oui ☐ non	
…									

25. **Pour vos productions SCOP courantes, vous pouvez avoir souscrit une autre forme de contrat avec votre (vos) coopérative (s) spécifiant seulement des modalités de mise en marché et de rémunération (« contrats de commercialisation »), sans cahier des charges de production.** Pour les quatre cultures du tableau suivant, indiquez la part des volumes vendus (en %) avec chaque mode de commercialisation proposé (campagne 2008/2009).

Cultures courantes	colza	blé tendre	orge hiver
Contrat classique (un seul prix moyen par campagne, pas d'engagement sur la quantité livrée)			
*Contrat périodique (un prix moyen par trimestre ou semestre, pas d'engagement sur la quantité livrée) **			
Contrat prix ferme (engagement sur un prix et une quantité à la fois)			
Contrat prix minimum (engagement sur un prix minimum et une quantité à la fois)			
Contrat de vente optionnelle (définition d'un prix objectif et engagement sur la quantité)			
Contrat de mise en dépôt (date de mise en marché libre et engagement sur la quantité)			
Absence de contrat (stockage à la ferme ou absence de stockage)			
TOTAL	100%	100%	100%

* *ex : paiement selon 4 prix correspondant au prix moyen observé à la fin de chaque trimestre*

26. **Dans les deux derniers modes de commercialisation, vous décidez vous-même de la (des) date(s) de mise en marché de votre production SCOP (et non pas la coopérative). De manière générale, quelle stratégie dominante adoptez-vous pour choisir cette (ces) date(s) ?** Cocher une seule case.

☐ tout est vendu immédiatement après la récolte
☐ la vente se fait quand il y a un besoin de trésorerie
☐ la vente se fait progressivement et régulièrement au cours de l'année
☐ la vente commence lorsque des objectifs de prix sont atteints
☐ la vente commence en fonction de l'évolution des cours (spéculation à la hausse)
☐ une partie est vendue immédiatement après la récolte, le reste lorsque des objectifs de prix sont atteints
☐ une partie est vendue immédiatement après la récolte, le reste en fonction de l'évolution des cours

Utilisez-vous régulièrement les marchés à terme agricoles (par vous-même ou via votre coopérative) ? ☐ OUI ☐ NON
Si oui, pourquoi ? ☐ pour bloquer votre prix de vente uniquement
☐ en souscrivant également à des options permettant de profiter d'une éventuelle hausse des cours

27. **Combien de fois avez-vous eu recours aux Dotations pour Aléas (DPA) ou pour Investissement (DPI) lors des cinq dernières années ?** fois

PARTIE 2

28. Connaissez-vous une de ces cultures pérennes énergétiques (CPE) ?

- miscanthus
☐ OUI, j'en cultive
☐ OUI, mais je n'en cultive pas
☐ NON

- panic érigé (switchgrass)
☐ OUI, j'en cultive
☐ OUI, mais je n'en cultive pas
☐ NON

- TTCR (récolte/4 ans)
☐ OUI, j'en cultive (TTCR de)
☐ OUI, mais je n'en cultive pas (TTCR de)
☐ NON

- TCR (récolte /10 ans)
☐ OUI, j'en cultive (TCR de)
☐ OUI, mais je n'en cultive pas (TCR de)
☐ NON

→ *Si <u>OUI</u> à une des espèces, poser la question29.*
→ *Si <u>NON</u> au miscanthus* **et** *au switchgrass, passer directement à la partie 2c.*

29. <u>MISCANTHUS</u>
Comment avez-vous entendu parler ?
Avez-vous eu ensuite d'autres sources d'information ? ☐ OUI ☐ NON
Si oui, lesquelles ?
Considérez-vous que l'information que vous avez pu obtenir sur le miscanthus soit suffisante ? ☐ OUI ☐ NON

<u>SWITCHGRASS</u>
Comment avez-vous entendu parler ?
Avez-vous eu ensuite d'autres sources d'information ? ☐ OUI ☐ NON
Si oui, lesquelles ?

<u>TCR/TTCR</u>
Comment avez-vous entendu parler ?
Avez-vous eu ensuite d'autres sources d'information ? ☐ OUI ☐ NON
Si oui, lesquelles ?

→ *Si <u>OUI, mais je n'en cultive pas</u> au miscanthus* **ou** *au switchgrass, poser la question 30.*
→ *Si <u>OUI, j'en cultive</u> au miscanthus* **ou** *au switchgrass, passer directement à la partie 2a.*

30. Vous êtes-vous déjà sérieusement posé la question de cultiver des CPE ?
- miscanthus ☐ OUI ☐ NON
- panic érigé (switchgrass) ☐ OUI ☐ NON

- TTCR (récolte/4 ans) ☐ OUI ☐NON
- TCR (récolte /10 ans) ☐ OUI ☐NON

→ ***Si <u>OUI</u> au miscanthus* ou *au switchgrass, passer à la partie 2b.***
→ ***Si <u>NON</u> au miscanthus* et *au switchgrass, passer à la partie 2c.***

PARTIE 2a : adopteurs

31. Où avez-vous implanté vos cultures pérennes énergétiques ? Localisez les îlots concernés sur les photos aériennes de votre exploitation. Dans le tableau, indiquez l'année où elles ont été semées/plantées, les rendements éventuellement déjà obtenus, et l'usage qui était fait de l'îlot les 3 années précédant l'implantation. Caractérisez les îlots si cela n'a pas déjà été fait en question 5.

CPE	*N° îlot*	*Surf. CPE (ha)*	*Année plant° (hiver)*	*Mode de faire-valoir*	*Critère 1*	*Critère 2*	*Critère 3*	*Critère 4*	*Utilisation en n-1*	*Utilisation en n-2*	*Utilisation en n-3*	*Type de sol*	*Distance (km)*	*Pente (%)*
☐ misc. ☐ switch				☐ direct ☐ indirect	☐ qualité ☐ éloign^{t} ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ qualité ☐ éloign^{t} ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ qualité ☐ éloign^{t} ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ qualité ☐ éloign^{t} ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ rotation de cultures : ☐ prairie permanente productive ☐ gel permanent ☐ autre :	☐ rotation de cultures : ☐ prairie permanente productive ☐ gel permanent ☐ autre :	☐ rotation de cultures : ☐ prairie permanente productive ☐ gel permanent ☐ autre :			
☐ misc. ☐ switch				☐ direct ☐ indirect	☐ qualité ☐ éloign^{t} ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ qualité ☐ éloign^{t} ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ qualité ☐ éloign^{t} ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ qualité ☐ éloign^{t} ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ rotation de cultures : ☐ prairie permanente productive ☐ gel permanent ☐ autre :	☐ rotation de cultures : ☐ prairie permanente productive ☐ gel permanent ☐ autre :	☐ rotation de cultures : ☐ prairie permanente productive ☐ gel permanent ☐ autre :			
☐ misc. ☐ switch				☐ direct ☐ indirect	☐ qualité ☐ éloign^{t} ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ qualité ☐ éloign^{t} ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ qualité ☐ éloign^{t} ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ qualité ☐ éloign^{t} ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ rotation de cultures : ☐ prairie permanente productive ☐ gel permanent ☐ autre :	☐ rotation de cultures : ☐ prairie permanente productive ☐ gel permanent ☐ autre :	☐ rotation de cultures : ☐ prairie permanente productive ☐ gel permanent ☐ autre :			

Les sols concernés sont-ils hydromorphes (excès eau) ?

ILOTS n° ________ , ________
Tous les ans ☐ ou seulement certaines années ☐ ?
Combien de temps ? tout l'hiver ☐ ou seulement ponctuellement ☐ ?

ILOTS n° ________ , ________
Tous les ans ☐ ou seulement certaines années ☐ ?
Combien de temps ? tout l'hiver ☐ ou seulement ponctuellement ☐ ?

Sont-ils séchants ?

ILOTS n° ________ , ________
Tous les ans ☐ ou seulement certaines années ☐ ?
Quand ? mois de à
Combien de temps ? semaines

ILOTS n° ________ , ________
Tous les ans ☐ ou seulement certaines années ☐ ?
Quand ? mois de à
Combien de temps ? semaines

S'il s'agit d'îlots qui n'ont pas été qualifiés de « marginaux » en début de questionnaire, pourquoi avez-vous fait ce choix de localisation ?

Quels rendements ont été obtenus ou sont espérés?
ILOT n°
2e année : (tB ou tMS/ha)
3e année : (tB ou tMS/ha)
4e année : (tB ou tMS/ha)

ILOT n°
2e année : (tB ou tMS/ha)
3e année : (tB ou tMS/ha)
4e année : (tB ou tMS/ha)

32. Lorsque vous avez décidé de cultiver des cultures pérennes énergétiques, possédiez-vous un débouché identifié pour ces cultures ? Lequel (lesquels), sous quelle forme [ensilé vrac (EV), ensilé pressé (EP), balles pressées (BP), bouchons ou pellets (PL)] **et à quel prix?** Cocher une seule case par intersection ligne/colonne.

	Part de la production totale en volume	*Débouché*	*Forme*	*Prix unité €/tB ou €/tMS à préciser*
Misc.	%	☐ autoconsommation ☐ vente directe particuliers ☐ transformateur (énergie) : ☐ autres usages (paillage, litière…) :	☐ EV ☐ EP ☐ BP ☐ PL	€/
	%	☐ autoconsommation ☐ vente directe particuliers ☐ transformateur (énergie) : ☐ autres usages (paillage, litière…) :	☐ EV ☐ EP ☐ BP ☐ PL	€/
	%	☐ autoconsommation ☐ vente directe particuliers ☐ transformateur (énergie) : ☐ autres usages (paillage, litière…) :	☐ EV ☐ EP ☐ BP ☐ PL	€/
…	%	aucun débouché identifié		
Switch. ….				

Somme des % par culture doit être égale à 100.

33. Et <u>aujourd'hui</u>, est-ce différent? ☐ OUI ☐ NON

Si oui, remplissez le tableau suivant.

	Part de la production totale en volume	*Débouché*	*Forme*	*Prix unité €/tB ou €/tMS à préciser*
Misc.	%	☐ autoconsommation ☐ vente directe particuliers ☐ transformateur (énergie) : ☐ autres usages (paillage, litière…) :	☐ EV ☐ EP ☐ BP ☐ PL	€/
	%	☐ autoconsommation ☐ vente directe particuliers ☐ transformateur (énergie) : ☐ autres usages (paillage, litière…) :	☐ EV ☐ EP ☐ BP ☐ PL	€/
	%	☐ autoconsommation ☐ vente directe particuliers ☐ transformateur (énergie) : ☐ autres usages (paillage, litière…) :	☐ EV ☐ EP ☐ BP ☐ PL	€/
…	%	aucun débouché identifié		
Switch. ….				

34. Avez-vous signé un contrat de production ? ☐ OUI ☐ NON

Si oui, remplissez le tableau suivant et répondez aux questions ci-dessous.

	Miscanthus	Switchgrass
1. Contrepartie		
2. Durée du contrat	récoltes (ou années)	
3. Prix de départ	€/tB à % de MS (ou €/tMS) ☐ sur pied ☐ bord de champ sans stockage ☐ bord de champ après stockage ☐ rendu usine	
4. Indexation du prix	% fixe + % de + % de + % de + % de	
5. Renégoc° du prix possible en cours de contrat	☐ oui ☐ non	
6. Engagement sur… (pénalités sinon)		
7. Risques pris en charge par l'agriculteur	Frais de ré-implantation en cas de non réussite ☐ oui ☐ non ☐ partiellement	

Comment ce contrat a-t-il été négocié ?

Mesurer l'implication de l'agriculteur dans la rédaction du contrat (au niveau des prix en particulier) : a-t-il pu négocier le contenu du contrat, ou était-ce « à prendre ou à laisser » ?

Autres informations du contrat :

35. Quelles aides publiques avez-vous perçu ou percevez-vous pour ces cultures (plusieurs réponses possibles) ?

☐ aucune
☐ aide Jachère Industrielle (PAC) (si planté avant 2010)
☐ aide Cultures Energétiques (PAC) (si planté avant 2010)
☐ subvention à l'implantation de €/ha ou % de la part de
☐ autres :

36. Quel est le montant des coûts de plantation ? €/ha, incluant
Comment sont-ils financés ? Il est possible de cocher plusieurs cases.

☐ trésorerie propre

☐ crédit bancaire : € la 1e année et € la 2e année
-> capital à rembourser sur ans à partir de la e année
-> intérêts de % à rembourser sur ans à partir de la e année

☐ avance de trésorerie par la contrepartie du contrat : : € la 1e année et € la 2e année
-> capital à rembourser sur ans à partir de la e année
-> intérêts de % à rembourser sur ans à partir de la e année

☐ autres :

37. Quelles sont les opérations culturales réalisées ? Qui les prend en charge ?

Opération culturale	*Prise en charge par l'agriculteur des coûts et du travail*	*Données techniques*
Préparation du terrain	- coût herbicides : oui : ☐ directement ☐ via ETA ☐ via contrepartie non : ☐ contrepartie ☐ sans objet - coût mécanisation : oui : ☐ directement ☐ via ETA ☐ via contrepartie non : ☐ contrepartie - main d'oeuvre : oui : ☐ directement ☐ via ETA ☐ via contrepartie non : ☐ contrepartie	- herbicides : /ha
Plantation de la culture	- coût semences : oui : ☐ directement ☐ via ETA ☐ via contrepartie non : ☐ contrepartie - coût engrais : oui : ☐ directement ☐ via ETA ☐ via contrepartie non : ☐ contrepartie ☐ sans objet - coût mécanisation : oui : ☐ directement ☐ via ETA ☐ via contrepartie non : ☐ contrepartie - main d'oeuvre : oui : ☐ directement ☐ via ETA ☐ via contrepartie - non : ☐ contrepartie	- engrais : uN /ha uP /ha uK /ha - matériel : - nb de personnes mobilisées
Désherbage et broyage	- coût herbicides : oui : ☐ directement ☐ via ETA ☐ via contrepartie non : ☐ contrepartie ☐ sans objet - coût mécanisation : oui : ☐ directement ☐ via ETA ☐ via contrepartie non : ☐ contrepartie	- herbicides : /ha année(s)

	- main d'oeuvre : oui : ☐ directement ☐ via ETA ☐ via contrepartie non : ☐ contrepartie	
Fertilisation	- coût engrais : oui : ☐ directement ☐ via ETA ☐ via contrepartie non : ☐ contrepartie ☐ sans objet - coût mécanisation : oui : ☐ directement ☐ via ETA ☐ via contrepartie non : ☐ contrepartie ☐ sans objet - main d'oeuvre : oui : ☐ directement ☐ via ETA ☐ via contrepartie non : ☐ contrepartie ☐ sans objet	- engrais : uN /ha année(s) uP /ha année(s) uK /ha année(s)
Traitement maladies (si nécessaire)	- coût pesticides : oui : ☐ directement ☐ via ETA ☐ via contrepartie non : ☐ contrepartie - coût mécanisation : oui : ☐ directement ☐ via ETA ☐ via contrepartie non : ☐ contrepartie - main d'œuvre : oui : ☐ directement ☐ via ETA ☐ via contrepartie non : ☐ contrepartie	
Récolte	- coût mécanisation : oui : ☐ directement ☐ via ETA ☐ via contrepartie non : ☐ contrepartie - main d'oeuvre : oui : ☐ directement ☐ via ETA ☐ via contrepartie non : ☐ contrepartie	- matériel : ☐ ensileuse (vrac) ☐ faucheuse-presse (balles pressées)
Stockage	- coût bâches plastiques ou coût hangar : oui : ☐ directement ☐ via ETA ☐ via contrepartie non : ☐ contrepartie - coût mécanisation : oui : ☐ directement ☐ via ETA ☐ via contrepartie non : ☐ contrepartie - main d'oeuvre : oui : ☐ directement ☐ via ETA ☐ via contrepartie non : ☐ contrepartie	-mode de stockage : ☐ sous abri ☐ sous bâche
Chargemen t	- coût mécanisation : oui : ☐ directement ☐ via ETA ☐ via contrepartie non : ☐ contrepartie - main d'oeuvre : oui : ☐ directement ☐ via ETA ☐ via contrepartie non : ☐ contrepartie	- nb de personnes mobilisées
Transport	- coût trajet : oui : ☐ directement ☐ via ETA ☐ via contrepartie non : ☐ contrepartie - main d'oeuvre : oui : ☐ directement ☐ via ETA ☐ via contrepartie non : ☐ contrepartie	-nb de personnes mobilisées
Remise en état parcelle	- coût mécanisation : oui : ☐ directement ☐ via ETA ☐ via contrepartie non : ☐ contrepartie ☐ ne sait pas - main d'œuvre : oui : ☐ directement ☐ via ETA ☐ via contrepartie non : ☐ contrepartie ☐ ne sait pas	

38. Une assurance dommage spécifique pour les parcelles en CPE est-elle souscrite ?
☐ OUI ☐ NON
Si la culture est sous contrat, est-ce une obligation explicite ? ☐ OUI ☐ NON
Si oui, la contrepartie la prend-elle en charge au moins partiellement ? ☐ OUI ☐ NON

39. Si les conditions contractuelles avec l'aval avaient été différentes, auriez-vous fait les mêmes choix en termes de culture, de surface, de localisation ? Expliquez.

- Absence de contrat et absence d'aide : ☐ OUI ☐ NON
Si oui, sur quelle surface : ha

- Contrat long terme avec accord sur le prix <u>sans</u> avance de trésorerie et <u>sans</u> aide PRN à l'implantation ☐ OUI ☐ NON
Si oui, sur quelle surface : ha

- Contrat long terme avec accord sur le prix <u>et</u> avance de trésorerie et <u>avec</u> aide PRN à l'implantation ☐ OUI ☐ NON
Si oui, sur quelle surface : ha

40. Si vous n'avez pas signé de contrat pour ces cultures,

-un autre mécanisme de partage de risque existe-t-il (société commune de commercialisation…) ?
☐ OUI ☐ NON
Si oui, lequel ?

-avez-vous contracté un prêt pour financer les coûts de plantation ?
☐ OUI ☐ NON
Quelles sont ses modalités ?
€ la 1e année
€ la 2e année
- capital à rembourser sur ans à partir de la année
- intérêts de % à rembourser sur ans à partir de la année

41. Quelles sont les raisons qui vous ont poussé à cultiver du miscanthus ? Détaillez.
Raison 1 :
Raison 2 :
Raison 3 :
Raison 4 :

42. Avez-vous hésité avec une autre culture énergétique ? ☐ OUI ☐ NON
Si oui, laquelle ?
Pourquoi ?
Si non, pourquoi ?

43. Pourquoi ne cultivez-vous pas de miscanthus sur une surface plus étendue ?
Raison 1 :
Raison 2 :
Raison 3 :
Raison 4 :

Etes-vous prêt aujourd'hui à étendre cette surface ? ☐ OUI ☐ NON
Si oui, jusqu'à quelle limite iriez-vous ? % SAU

44. Quels sont, <u>pour vous</u>, et dans vos conditions d'exploitation (sur la/les parcelle(s) choisies), les risques les plus importants que vous associez à la production du miscanthus et de blé tendre ?
Indiquez NSP, 1, 2, 3, 4, ou 5, en fonction de leur probabilité d'occurrence <u>et</u> de leur impact potentiel (<u>négatif</u>) sur la rentabilité économique de l'activité si elles devaient se réaliser, <u>aujourd'hui et dans le futur</u> (*NSP= ne sait pas, 1= pas important du tout, 2= peu important, 3= moyennement important, 4= important, 5= très important).*

	<u>Misc.</u>	<u>Blé t.</u>
PRODUCTION		
- maladie :	☐	☐
- ravageurs :	☐	☐
- accident climatique (grêle, sécheresse) :	☐	☐
- concurrence des mauvaises herbes :	☐	☐
- incendie :	☐	☐
TECHNIQUE		
- erreurs dans la conduite ou la récolte :	☐	☐
- erreurs dans le choix de la parcelle :	☐	☐
MARCHE		
- instabilité des prix :	☐	☐
- manque de débouchés :	☐	☐
ECONOMIQUE		
- instabilité des coûts de production :	☐	☐
- augmentation des coûts de main d'œuvre (ou baisse de sa disponibilité) : ☐ sans objet	☐	☐
- augmentation du coût du crédit : ☐ sans objet	☐	☐
- dégradation de la valeur de la parcelle :	☐	☐
POLITIQUE		
- relations avec le bailleur de la parcelle : ☐ sans objet	☐	☐
- nouvelles normes environnementales :	☐	☐
- risque de contrepartie (contrats) :	☐	☐

45. Quels sont, <u>pour vous</u>, et dans vos conditions d'exploitation, les autres éléments qui caractérisent la production de miscanthus ?

Indiquez NSP, 1, 2, 3, 4, ou 5, selon votre degré d'accord avec les propositions suivantes (*NSP= ne sait pas, 1= pas du tout d'accord, 2=plutôt pas d'accord, 3= ni en désaccord, ni d'accord, 4= plutôt d'accord, 5= tout à fait d'accord).*

- Le miscanthus est bénéfique pour l'environnement : ☐
- Il existe une forte incertitude sur les rendements : ☐
- En l'absence de contrats, il existe une forte incertitude sur les débouchés : ☐
- La production de miscanthus demande un appui technique : ☐
- Le miscanthus demande un investissement initial élevé : ☐
- Le miscanthus permet de dégager du temps de manière significative : ☐
- Le miscanthus est une culture rentable par rapport à une rotation traditionnelle : ☐

PARTIE 2b : non adopteurs s'étant posé la question de l'adoption (et donc ayant une bonne connaissance des CPE)

46. Lorsque vous avez envisagé de cultiver des CPE, sur quel(s) îlot(s) pensiez-vous le faire ?

☐ n'avait pas pensé à une localisation en particulier.
☐ l'un des îlots « peu rentables » décrits dans la première partie,
i.e. l'îlot (les îlots) n° : , ,
☐ une autre type d'îlot spécifique :
☐ un îlot n'appartenant à aucune des deux catégories précédentes : compléter le tableau ci-dessous

CPE	*N° îlot*	*Surf. CPE (ha)*	*Mode de faire-valoir*	*Critère 1*	*Critère 2*	*Critère 3*	*Critère 4*	*Utilisation en n-1*	*Utilisation en n-2*	*Utilisation en n-3*	*Type de sol*	*Distance (km)*	*Pente (%)*
☐ misc. ☐ switch			☐ direct ☐ indirect	☐ qualité ☐ éloign^t ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ qualité ☐ éloign^t ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ qualité ☐ éloign^t ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ qualité ☐ éloign^t ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ rotation de cultures : ☐ prairie permanente productive ☐ gel permanent ☐ autre :	☐ rotation de cultures : ☐ prairie permanente productive ☐ gel permanent ☐ autre :	☐ rotation de cultures : ☐ prairie permanente productive ☐ gel permanent ☐ autre :			
☐ misc. ☐ switch			☐ direct ☐ indirect	☐ qualité ☐ éloign^t ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ qualité ☐ éloign^t ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ qualité ☐ éloign^t ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ qualité ☐ éloign^t ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ rotation de cultures : ☐ prairie permanente productive ☐ gel permanent ☐ autre :	☐ rotation de cultures : ☐ prairie permanente productive ☐ gel permanent ☐ autre :	☐ rotation de cultures : ☐ prairie permanente productive ☐ gel permanent ☐ autre :			
☐ misc. ☐ switch			☐ direct ☐ indirect	☐ qualité ☐ éloign^t ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ qualité ☐ éloign^t ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ qualité ☐ éloign^t ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ qualité ☐ éloign^t ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ rotation de cultures : ☐ prairie permanente productive ☐ gel permanent ☐ autre :	☐ rotation de cultures : ☐ prairie permanente productive ☐ gel permanent ☐ autre :	☐ rotation de cultures : ☐ prairie permanente productive ☐ gel permanent ☐ autre :			

Les sols concernés sont-ils hydromorphes (excès eau) ?

ILOTS n° ,
Tous les ans ☐ ou seulement certaines années ☐ ?
Combien de temps ? tout l'hiver ☐ ou seulement ponctuellement ☐ ?

ILOTS n° ,
Tous les ans ☐ ou seulement certaines années ☐ ?
Combien de temps ? tout l'hiver ☐ ou seulement ponctuellement ☐ ?

Sont-ils séchants ?

ILOTS n° ,	ILOTS n° ,
Tous les ans ☐ ou seulement certaines années ☐ ?	Tous les ans ☐ ou seulement certaines années ☐ ?
Quand ? mois de à	Quand ? mois de à
Combien de temps ? semaines	Combien de temps ? semaines

47. Quelles auraient été les conditions de vente ?

☐ Absence de contrat

☐ Contrat long terme avec accord sur le prix sans avance de trésorerie et sans aide PRN à l'implantation de type (Aiserey2 p ex)

☐ Contrat long terme avec accord sur le prix et avance de trésorerie et avec aide PRN à l'implantation de type (Aiserey1 p ex)

48. Si les conditions contractuelles avec l'aval avaient été différentes, auriez-vous fait les mêmes choix en termes de culture, de surface, de localisation ? Expliquez.

- Absence de contrat et absence d'aide : ☐ OUI ☐ NON

Si oui, sur quelle surface : ha

- Contrat long terme avec accord sur le prix sans avance de trésorerie et sans aide PRN à l'implantation ☐ OUI ☐ NON

Si oui, sur quelle surface : ha

- Contrat long terme avec accord sur le prix et avance de trésorerie et avec aide PRN à l'implantation ☐ OUI ☐ NON

Si oui, sur quelle surface : ha

49. Quels sont les éléments qui vous intéressaient dans la culture du miscanthus (au sens du système de production) ? Détaillez.

Raison 1 :
Raison 2 :
Raison 3 :
Raison 4 :

50. Quelles sont les raisons qui vous ont finalement poussé à ne pas planter de miscanthus ? Détaillez.

Raison 1 :
Raison 2 :
Raison 3 :
Raison 4 :

51. Quels sont, pour vous, et dans vos conditions d'exploitation (sur la/les parcelle(s) choisies), les risques les plus importants que vous associez à la production du miscanthus et de blé tendre ?

Indiquez NSP, 1, 2, 3, 4, ou 5, en fonction de leur probabilité d'occurrence et de leur impact potentiel (négatif) sur la rentabilité économique de l'activité si elles devaient se réaliser, aujourd'hui et dans le futur (*NSP= ne sait pas, 1= pas important du tout, 2= peu important, 3= moyennement important, 4= important, 5= très important).*

	Misc.	Blé t.
PRODUCTION		
- maladie :	☐	☐
- ravageurs :	☐	☐
- accident climatique (grêle, sécheresse) :	☐	☐
- concurrence des mauvaises herbes :	☐	☐
- incendie :	☐	☐
TECHNIQUE		
- erreurs dans la conduite ou la récolte :	☐	☐
- erreurs dans le choix de la parcelle :	☐	☐
MARCHE		
- instabilité des prix :	☐	☐
- manque de débouchés :	☐	☐
ECONOMIQUE		
- instabilité des coûts de production :	☐	☐
- augmentation des coûts de main d'œuvre (ou baisse de sa disponibilité) : ☐ sans objet	☐	☐
- augmentation du coût du crédit : ☐ sans objet	☐	☐
- dégradation de la valeur de la parcelle :	☐	☐
POLITIQUE		
- relations avec le bailleur de la parcelle : ☐ sans objet	☐	☐
- nouvelles normes environnementales :	☐	☐
- risque de contrepartie (contrats) :	☐	☐

52. Quels sont, pour vous, et dans vos conditions d'exploitation, les autres éléments qui caractérisent la production de miscanthus ?

Indiquez NSP, 1, 2, 3, 4, ou 5, selon votre degré d'accord avec les propositions suivantes (*NSP= ne sait pas, 1= pas du tout d'accord, 2=plutôt pas d'accord, 3= ni en désaccord, ni d'accord, 4= plutôt d'accord, 5= tout à fait d'accord).*

- Le miscanthus est bénéfique pour l'environnement : ☐
- Il existe une forte incertitude sur les rendements : ☐

- En l’absence de contrats, il existe une forte incertitude sur les débouchés : ☐
- La production de miscanthus demande un appui technique : ☐
- Le miscanthus demande un investissement initial élevé : ☐
- Le miscanthus permet de dégager du temps de manière significative : ☐
- Le miscanthus est une culture rentable par rapport à une rotation traditionnelle : ☐

PARTIE 2c : non adopteurs ne s'étant pas posé la question de l'adoption

53. Quels sont, pour vous, et dans vos conditions d'exploitation (sur la/les parcelle(s) choisies), les risques les plus importants que vous associez à la production du miscanthus et de blé tendre ?

Indiquez NSP, 1, 2, 3, 4, ou 5, en fonction de leur probabilité d'occurrence et de leur impact potentiel (négatif) sur la rentabilité économique de l'activité si elles devaient se réaliser, aujourd'hui et dans le futur (*NSP= ne sait pas, 1= pas important du tout, 2= peu important, 3= moyennement important, 4= important, 5= très important).*

	Misc.	Blé t.
PRODUCTION		
- maladie :	☐	☐
- ravageurs :	☐	☐
- accident climatique (grêle, sécheresse) :	☐	☐
- concurrence des mauvaises herbes :	☐	☐
- incendie :	☐	☐
TECHNIQUE		
- erreurs dans la conduite ou la récolte :	☐	☐
- erreurs dans le choix de la parcelle :	☐	☐
MARCHE		
- instabilité des prix :	☐	☐
- manque de débouchés :	☐	☐
ECONOMIQUE		
- instabilité des coûts de production :	☐	☐
- augmentation des coûts de main d'œuvre (ou baisse de sa disponibilité) : ☐ sans objet	☐	☐
- augmentation du coût du crédit : ☐ sans objet	☐	☐
- dégradation de la valeur de la parcelle :	☐	☐
POLITIQUE		
- relations avec le bailleur de la parcelle : ☐ sans objet	☐	☐
- nouvelles normes environnementales :	☐	☐
- risque de contrepartie (contrats) :	☐	☐

54. Quels sont, pour vous, et dans vos conditions d'exploitation, les autres éléments qui caractérisent la production de miscanthus ?
Indiquez NSP, 1, 2, 3, 4, ou 5, selon votre degré d'accord avec les propositions suivantes (*NSP= ne sait pas, 1= pas du tout d'accord, 2=plutôt pas d'accord, 3= ni en désaccord, ni d'accord, 4= plutôt d'accord, 5= tout à fait d'accord).*

- Le miscanthus est bénéfique pour l'environnement :	
- Il existe une forte incertitude sur les rendements :	
- En l'absence de contrats, il existe une forte incertitude sur les débouchés :	
- La production de miscanthus demande un appui technique :	
- Le miscanthus demande un investissement initial élevé :	
- Le miscanthus permet de dégager du temps de manière significative :	
- Le miscanthus est une culture rentable par rapport à une rotation traditionnelle :	

Nous allons maintenant vous présenter de manière synthétique le miscanthus et/ou le switchgrass en termes techniques, économiques et environnementaux. Il s'agit d'une présentation objective à partir des informations actuellement disponibles (source : fiches cultures du RMT Biomasse) .

55. Souhaiteriez-vous dans ces conditions implanter du miscanthus ?
☐ OUI ☐ NON

56. Si oui, pourquoi ? Détaillez.
Raison 1 :
Raison 2 :
Raison 3 :
Raison 4 :

57. Si non, pourquoi ? Détaillez.
Raison 1 :
Raison 2 :
Raison 3 :
Raison 4 :

58. Si non, quels sont les éléments qui vous intéressent néanmoins dans la culture du miscanthus (au sens du système de production) ? Détaillez.
Raison 1 :
Raison 2 :
Raison 3 :
Raison 4 :

59. Sur quel(s) îlot(s) voyez-vous ce miscanthus ?

☐ ne sait pas

☐ l'un des îlots « peu rentables » décrits dans la première partie,
i.e. l'îlot (les îlots) n° : , ,

☐ une autre type d'îlot spécifique :

☐ un îlot n'appartenant à aucune des deux catégories précédentes : compléter le tableau ci-dessous

CPE	*N° îlot*	*Surf. CPE (ha)*	*Mode de faire-valoir*	*Critère 1*	*Critère 2*	*Critère 3*	*Critère 4*	*Utilisation en n-1*	*Utilisation en n-2*	*Utilisation en n-3*	*Type de sol*	*Distance (km)*	*Pente (%)*
☐ misc. ☐ switch			☐ direct ☐ indirect	☐ qualité ☐ éloignt ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ qualité ☐ éloignt ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ qualité ☐ éloignt ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ qualité ☐ éloignt ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ rotation de cultures : ☐ prairie permanente productive ☐ gel permanent ☐ autre :	☐ rotation de cultures : ☐ prairie permanente productive ☐ gel permanent ☐ autre :	☐ rotation de cultures : ☐ prairie permanente productive ☐ gel permanent ☐ autre :			
☐ misc. ☐ switch			☐ direct ☐ indirect	☐ qualité ☐ éloignt ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ qualité ☐ éloignt ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ qualité ☐ éloignt ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ qualité ☐ éloignt ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ rotation de cultures : ☐ prairie permanente productive ☐ gel permanent ☐ autre :	☐ rotation de cultures : ☐ prairie permanente productive ☐ gel permanent ☐ autre :	☐ rotation de cultures : ☐ prairie permanente productive ☐ gel permanent ☐ autre :			
☐ misc. ☐ switch			☐ direct ☐ indirect	☐ qualité ☐ éloignt ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ qualité ☐ éloignt ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ qualité ☐ éloignt ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ qualité ☐ éloignt ☐ taille ☐ pente ☐ forme irrégul. ☐ autres:	☐ rotation de cultures : ☐ prairie permanente productive ☐ gel permanent ☐ autre :	☐ rotation de cultures : ☐ prairie permanente productive ☐ gel permanent ☐ autre :	☐ rotation de cultures : ☐ prairie permanente productive ☐ gel permanent ☐ autre :			

Les sols concernés sont-ils hydromorphes (excès eau) ?

ILOTS n° ,

Tous les ans ☐ ou seulement certaines années ☐ ?

Combien de temps ? tout l'hiver ☐ ou seulement ponctuellement ☐ ?

ILOTS n° ,

Tous les ans ☐ ou seulement certaines années ☐ ?

Combien de temps ? tout l'hiver ☐ ou seulement ponctuellement ☐ ?

Sont-ils séchants ?

ILOTS n° ,
Tous les ans ☐ ou seulement certaines années ☐ ?
Quand ? mois de à
Combien de temps ? semaines

ILOTS n° ,
Tous les ans ☐ ou seulement certaines années ☐ ?
Quand ? mois de à
Combien de temps ? semaines

60. Si les conditions contractuelles avec l'aval avaient été différentes de celles proposées, auriez-vous fait les mêmes choix en termes de culture, de surface, de localisation ? Expliquez.

- Absence de contrat et absence d'aide : ☐ OUI ☐ NON
Si oui, sur quelle surface : ha

- Contrat long terme avec accord sur le prix sans avance de trésorerie et sans aide PRN à l'implantation ☐ OUI ☐ NON
Si oui, sur quelle surface : ha

- Contrat long terme avec accord sur le prix et avance de trésorerie et avec aide PRN à l'implantation ☐ OUI ☐ NON
Si oui, sur quelle surface : ha

PARTIE 3 PERCEPTIONS ET ANTICIPATIONS

61. De manière générale, quels objectifs poursuivez-vous dans votre métier d'agriculteur ?
Choisissez 3 des items suivants et classez-les par ordre d'importance *(1= le plus important, 3= le moins important)*.
- Avoir des relations sociales ☐
- Avoir une exploitation avec de bonnes performances environnementales ☐
- Conduire des machines agricoles (tracteurs) ☐
- Continuer à être agriculteur ☐
- Dégager du temps pour d'autres activités (syndicalisme, gîte rural…) ☐
- Dégager du temps pour la famille, les loisirs ☐
- Entretenir le paysage ☐
- Etre apprécié de la société et donner une bonne image de l'agriculture ☐
- Etre indépendant des aides publiques ☐
- Générer un revenu stable/éviter les fluctuations de revenu ☐
- Maximiser/augmenter le revenu ☐
- Minimiser les dettes ☐
- Poursuivre la tradition familiale ☐
- Produire davantage ☐
- Produire de la nourriture de bonne qualité ☐
- Transmettre une exploitation avec des terres/ressources naturelles en bon/meilleur état ☐
- Transmettre une exploitation avec plus d'actifs (capitalisation) ☐
- Autres : ☐

62. Quelle est selon vous la probabilité d'occurrence des événements suivants ?
Indiquez 1, 2, 3, 4, ou 5, selon votre degré d'accord avec les propositions suivantes (*1= pas du tout probable, 2=peu probable, 3= moyennement probable, 4= probable, 5= tout à fait probable).*
- La PAC va bientôt soutenir spécifiquement les cultures lignocellulosiques, dont le miscanthus. ☐
- La demande de biomasse énergie va augmenter. ☐

63. En juin 2009, la cotation du blé tendre rendu Rouen était de 135€/t (Agreste).
A combien estimez-vous cette cotation à moyen terme (échéances de 5 à 10 ans) (inflation négligée) ?

Indiquez la valeur la plus basse qu'elle pourrait atteindre : €/t
Indiquez la valeur la plus haute qu'elle pourrait atteindre : €/t

Pensez-vous que, en tendance, ce prix va ☐ augmenter, ☐ diminuer, ou ☐ rester au même niveau qu'aujourd'hui ?

64. En 2009, le prix du gazole-fioul domestique était de 40€ HT/100 l en moyenne (DIREM).
A combien estimez-vous ce prix à des échéances de 5 et 10 ans (inflation négligée) ?

Indiquez la valeur la plus basse qu'elle pourrait atteindre : €/t
Indiquez la valeur la plus haute qu'elle pourrait atteindre : €/t

Pensez-vous que, en tendance, ce prix va ☐ augmenter, ☐ diminuer, ou ☐rester au même niveau qu'aujourd'hui ?

65. Certaines personnes aiment renouveler sans cesse leurs activités, tandis que d'autres préfèrent se perfectionner dans ce qu'elles savent faire.

Indiquez 1, 2, 3, 4, ou 5, selon votre degré d'accord avec les propositions suivantes (*1= pas du tout d'accord, 2=plutôt pas d'accord, 3= ni en désaccord, ni d'accord, 4= plutôt d'accord, 5= tout à fait d'accord).*

- J'aime essayer de nouvelles techniques ou productions sur mon exploitation : ☐
- Lorsqu'il s'agit d'une technique ou d'une production encore peu répandue, je préfère voir ses résultats dans d'autres exploitations avant de l'essayer : ☐

66. Certaines personnes aiment prendre des risques, tandis que d'autres sont plus réticentes. Comment qualifieriez- vous <u>votre</u> attitude par rapport à la prise de risque ?

Indiquez 1, 2, 3, 4, ou 5, en fonction de votre propension à prendre des risques (*1= très réticent, 2= assez réticent, 3= ni réticent, ni volontaire, 4= assez volontaire, 5= très volontaire).*

- De manière générale (tous domaines confondus) : ☐
- Dans vos choix de production agricole : ☐
- Dans vos choix agricoles financiers et d'investissement : ☐
- Dans vos choix de mise en marché : ☐

67. De manière générale, diriez-vous que ? :

Cocher une des deux réponses.

- ☐ On peut faire confiance à la majorité des personnes.
- ☐ On n'est jamais trop prudent quant à la confiance qu'on peut avoir dans les personnes.

PARTIE 4 INFORMATIONS GENERALES

CARACTERISTIQUES GENERALES

68. Année de naissance

69. En quelle année avez-vous pris la direction (à votre compte ou comme salarié) ?
- de cette exploitation
- de votre première exploitation ?

70. Niveau de formation initial
☐ Primaire (certificat d'études)
☐ Secondaire courte (CAP, BEP, BEPC, BEA…)
☐ Secondaire longue (Bac, BTA, …
☐ Supérieure (facultés, DUT, BTS...)

71. Nb de personnes composant le foyer fiscal ?

72. Conjoint ☐ OUI ☐ NON

73. Nb d'enfants à charge et âge

Enfant 1 ans
Enfant 2 ans
Enfant 3 ans
Enfant 4 ans

MATERIEL

74. Certains de vos équipements sont-ils mis en commun ?
☐ OUI (CUMA) ☐ OUI (hors CUMA) ☐ NON

75. Avez-vous recours à une ETA pour réaliser certains de vos travaux ? ☐ OUI ☐ NON
Lesquels ?

Pour la récolte en particulier ? ☐ OUI ☐ NON
Pour quelle raison ?
☐ limiter l'investissement
☐ faire face aux pointes de travail
☐ autres :

76. Utilisez-vous de l'huile végétale pure (colza) **comme carburant ?** ☐ OUI ☐ NON

TEMPS DE TRAVAIL

77. Temps de travail pour l'exploitation
TOTAL : UTH, dont :

main d'œuvre	*familiale*	*non familiale*
permanente	UTH salariées UTH non salariées	UTH salariées UTH non salariées
saisonnière *ou occasionnelle* *(yc stagiaires)*	UTH salariées UTH non salariées	UTH salariées UTH non salariées

78. Travail effectué par du personnel d'ETA ou de CUMA

ETA : journées (8h) CUMA : journées (8h)

79. Activité hors production agricole (vous-même)

	Actuellement	*Dans le passé*
aucune	☐	☐
non rémunérée	☐	☐
salarié agricole (cadre, contremaître, agent de maîtrise…)	☐	☐
technicien agricole (contrôleur laitier, inséminateur…)	☐	☐
ouvrier agricole (éleveur, conducteur d'engins…)	☐	☐
ETA, exploitant forestier…de 0 à 9 salariés	☐	☐
ETA, exploitant forestier…> 10 salariés	☐	☐
chef d'ent. (artisan, commerçant et assimilé) de 0 à 9 sal.	☐	☐
chef d'ent. (artisan, commerçant et assimilé) > 10 sal.	☐	☐
profession libérale	☐	☐
élu (maire, président de coop…)	☐	☐
autre cadre, prof. intellectuelle et artistique	☐	☐
profession intermédiaire (instituteur, infirmier, technicien, …)	☐	☐
employé	☐	☐
ouvrier non agricole	☐	☐

Temps consacré à cette activité

☐ moins de ¼ temps (- de 10h/sem)
☐ ¼ à < ½ temps (10 à <20h/sem)
☐ ½ à < ¾ temps (20 à <30h/sem)
☐ ¾ à < temps complet (30 à <39h/sem)
☐ temps complet (39h et plus/sem)

80. Activité hors production agricole (votre conjoint)

	Actuellement	*Dans le passé*
aucune	☐	☐
non rémunérée	☐	☐
salarié agricole (cadre, contremaître, agent de maîtrise…)	☐	☐
technicien agricole (contrôleur laitier, inséminateur…)	☐	☐

ouvrier agricole (éleveur, conducteur d'engins…)	☐	☐
ETA, exploitant forestier…de 0 à 9 salariés	☐	☐
ETA, exploitant forestier…> 10 salariés	☐	☐
chef d'ent. (artisan, commerçant et assimilé) de 0 à 9 sal.	☐	☐
chef d'ent. (artisan, commerçant et assimilé) > 10 sal.	☐	☐
profession libérale	☐	☐
élu (maire, président de coop…)	☐	☐
autre cadre, prof. intellectuelle et artistique	☐	☐
profession intermédiaire (instituteur, infirmier, technicien, …)	☐	☐
employé	☐	☐
ouvrier non agricole	☐	☐

Temps qu'il/elle consacre à cette activité

☐ moins de ¼ temps (- de 10h/sem)
☐ ¼ à < ½ temps (10 à <20h/sem)
☐ ½ à < ¾ temps (20 à <30h/sem)
☐ ¾ à < temps complet (30 à <39h/sem)
☐ temps complet (39h et plus/sem)

81. Quels congés prenez-vous? semaine(s) par an

PRODUCTION

82. Assolement campagne 2008/2009 et rendements

Culture	*Surface*	*Rendements sur 5 ans*
	ha	/ha ; /ha ; /ha ; /ha ; /ha
	ha	/ha ; /ha ; /ha ; /ha ; /ha
	ha	/ha ; /ha ; /ha ; /ha ; /ha
	ha	/ha ; /ha ; /ha ; /ha ; /ha
	ha	/ha ; /ha ; /ha ; /ha ; /ha
	ha	/ha ; /ha ; /ha ; /ha ; /ha
	ha	/ha ; /ha ; /ha ; /ha ; /ha
	ha	/ha ; /ha ; /ha ; /ha ; /ha
	ha	/ha ; /ha ; /ha ; /ha ; /ha
	ha	/ha ; /ha ; /ha ; /ha ; /ha

83. Systèmes de culture

Système de culture	*Succession*	*Surface*	*Type de terre*	*Irrigation*
1	culture 1 : culture 2 : culture 3 : culture 4 : culture 5 :	ha		☐Oui ☐Non
2	culture 1 : culture 2 : culture 3 :	ha		☐Oui ☐Non

	culture 4 : culture 5 :			
3	culture 1 : culture 2 : culture 3 : culture 4 : culture 5 :	ha		☐Oui ☐Non
4	culture 1 : culture 2 : culture 3 : culture 4 : culture 5 :	ha		☐Oui ☐Non
…				

84. Systèmes d'élevage

Système d'élevage	*Espèce*	*Nombre total d'animaux*	*Nombre de mères*	*Nombre d'UGB*
1	☐ bovin viande maigre ☐ bovin viande gras ☐ bovin lait ☐ autres :	têtes	têtes	UGB
2	☐ bovin viande maigre ☐ bovin viande gras ☐ bovin lait ☐ autres :	têtes	têtes	UGB
3	☐ bovin viande maigre ☐ bovin viande gras ☐ bovin lait ☐ autres :	têtes	têtes	UGB
4	☐ bovin viande maigre ☐ bovin viande gras ☐ bovin lait ☐ autres :	têtes	têtes	UGB
…				

85. Autres activités agricoles (sous-produit ou transformation) :

86. Production d'énergie renouvelable pour l'autoconsommation
☐ OUI ☐NON
Si oui, laquelle (lesquelles) ?

87. Transformation de bois de l'exploitation pour la vente ? ☐ OUI ☐NON

88. Autres productions d'énergie renouvelable pour la vente (énergie éolienne, combustion paille…) ? ☐ OUI ☐NON
Si oui, laquelle (lesquelles) ?

89. Avez-vous votre permis de chasse ? ☐ OUI ☐NON

DYNAMIQUE D'EVOLUTION

90. Qui va vous succéder comme chef d'exploitation ?

☐ sans objet (ne se pose pas encore la question)
☐ coexploitant de cette exploitation agricole
☐ membre de la famille
☐ autre successeur
☐ pas de successeur (l'exploitation va disparaître)
☐ inconnu à ce jour (se pose la question mais ne sait pas encore)

91. Des changements importants sont-ils intervenus sur votre exploitation depuis les 5-10 dernières années ? ☐ OUI ☐ NON

Si oui, pouvez-vous les dater, les caractériser en quelques mots et les quantifier?

Changement	*Année*	*Concerne*	*Explication***
1		☐ surface ☐ main d'œuvre ☐ orientation de la production (cultures) ☐ orientation de la production (élevage) ☐ mode de production ☐ matériel ☐ autre :	
2		☐ surface ☐ main d'œuvre ☐ orientation de la production (cultures) ☐ orientation de la production (élevage) ☐ mode de production ☐ matériel ☐ autre :	
3		☐ surface ☐ main d'œuvre ☐ orientation de la production (cultures) ☐ orientation de la production (élevage) ☐ mode de production ☐ matériel ☐ autre :	
4		☐ surface ☐ main d'œuvre ☐ orientation de la production (cultures) ☐ orientation de la production (élevage) ☐ mode de production	

		☐ matériel ☐ autre :	
5		…	
…			

92. Des changements importants sont-ils prévus sur votre exploitation dans les 5 prochaines années ? ☐ OUI ☐ NON

Si oui, pouvez-vous les dater, les caractériser en quelques mots et les quantifier?

Changement	*Année*	*Concerne*	*Explication*
1		☐ surface ☐ main d'œuvre ☐ orientation de la production (cultures) ☐ orientation de la production (élevage) ☐ mode de production ☐ matériel ☐ autre :	
2		☐ surface ☐ main d'œuvre ☐ orientation de la production (cultures) ☐ orientation de la production (élevage) ☐ mode de production ☐ matériel ☐ autre :	
3		☐ surface ☐ main d'œuvre ☐ orientation de la production (cultures) ☐ orientation de la production (élevage) ☐ mode de production ☐ matériel ☐ autre :	
4		☐ surface ☐ main d'œuvre ☐ orientation de la production (cultures) ☐ orientation de la production (élevage) ☐ mode de production ☐ matériel ☐ autre :	
5		…	
…			

93. Avez-vous cherché dans les 5-10 dernières années à diminuer la consommation énergétique de votre exploitation ? ☐ OUI ☐ NON

Si oui, comment ?

RESULTATS ECONOMIQUES

Dans cette dernière partie, nous vous posons un certain nombre de questions relatives à vos revenus. Ces éléments nous permettrons de mettre en relation le contexte économique dans lequel vous évoluez et les décisions que vous avez pris ou auriez pris face à la possibilité de cultiver des CPE. Ils seront aussi rapprochés de vos choix par rapport à des situations plus ou moins risquées. Des études menées sur d'autres innovations agricoles ont en effet montré que les facteurs économiques jouaient un rôle important dans l'adoption d'une innovation, en particulier si elle est risquée. Afin que l'effet du contexte économique soit correctement quantifié statistiquement, nous avons besoin de données assez précises, et homogènes entre les différentes personnes que nous interrogeons. L'idéal serait donc que nous nous référions à vos documents comptables d'exploitation, et à votre avis d'imposition, si possible des 5 dernières années. De cette façon, nous recueillons des données objectives et comparables entre individus.

94. Part que représentent les activités hors exploitation agricole (vous <u>et</u> votre conjoint) dans le revenu total du ménage (Revenu Fiscal de Référence), en moyenne sur les 5 dernières années. %

95. Investissez-vous des capitaux provenant de votre activité agricole dans des activités extra-agricoles ? ☐ OUI dans : ☐ NON

96. Dans quel intervalle se trouve le RFR (Revenu Fiscal de Référence) de votre foyer correspondant aux revenus 2008 (impôt payé en 2009), en moyenne ?

☐ 0≤ ... <10 k€	☐ 30≤ ... <40 k€	☐ 60≤ ... <70 k€	☐ 90≤ ... <100 k€	☐ … ≥ 120 k€
☐ 10≤ … <20 k€	☐ 40≤ ... <50 k€	☐ 70≤ ... <80 k€	☐ 100≤ ... <110 k€	
☐ 20≤ … <30 k€	☐ 50≤ ... <60 k€	☐ 80≤ ... <90 k€	☐ 110≤ ... <120 k€	

Dans quel intervalle se trouve le RCAI (Résultat Courant avant Impôt) de votre exploitation pour les 5 derniers exercices comptables ?

Année 1	☐ 0≤ ... <10 k€	☐ 30≤ ... <40 k€	☐ 60≤ ... <70 k€	☐ 90≤ ... <100 k€	☐ … ≥ 120 k€
	☐ 10≤ … <20 k€	☐ 40≤ ... <50 k€	☐ 70≤ ... <80 k€	☐ 100≤ ... <110 k€	
	☐ 20≤ … <30 k€	☐ 50≤ ... <60 k€	☐ 80≤ ... <90 k€	☐ 110≤ ... <120 k€	
Année 2	☐ 0≤ ... <10 k€	☐ 30≤ ... <40 k€	☐ 60≤ ... <70 k€	☐ 90≤ ... <100 k€	☐ … ≥ 120 k€
	☐ 10≤ … <20 k€	☐ 40≤ ... <50 k€	☐ 70≤ ... <80 k€	☐ 100≤ ... <110 k€	
	☐ 20≤ … <30 k€	☐ 50≤ ... <60 k€	☐ 80≤ ... <90 k€	☐ 110≤ ... <120 k€	
Année 3	☐ 0≤ ... <10 k€	☐ 30≤ ... <40 k€	☐ 60≤ ... <70 k€	☐ 90≤ ... <100 k€	☐ … ≥ 120 k€
	☐ 10≤ … <20 k€	☐ 40≤ ... <50 k€	☐ 70≤ ... <80 k€	☐ 100≤ ... <110 k€	
	☐ 20≤ … <30 k€	☐ 50≤ ... <60 k€	☐ 80≤ ... <90 k€	☐ 110≤ ... <120 k€	
Année 4	☐ 0≤ ... <10 k€	☐ 30≤ ... <40 k€	☐ 60≤ ... <70 k€	☐ 90≤ ... <100 k€	☐ … ≥ 120 k€
	☐ 10≤ … <20 k€	☐ 40≤ ... <50 k€	☐ 70≤ ... <80 k€	☐ 100≤ ... <110 k€	
	☐ 20≤ … <30 k€	☐ 50≤ ... <60 k€	☐ 80≤ ... <90 k€	☐ 110≤ ... <120 k€	
Année 5	☐ 0≤ ... <10 k€	☐ 30≤ ... <40 k€	☐ 60≤ ... <70 k€	☐ 90≤ ... <100 k€	☐ … ≥ 120 k€

	☐ 10≤ … <20 k€ ☐ 40≤ ... <50 k€ ☐ 70≤ ... <80 k€ ☐ 100≤ ... <110 k€ ☐ 20≤ … <30 k€ ☐ 50≤ ... <60 k€ ☐ 80≤ ... <90 k€ ☐ 110≤ ... <120 k€

97. Quelle est la variation de vos revenus agricoles (ce qui est utilisé pour votre consommation personnelle) d'une année à l'autre ?

☐ ± 20% ☐ de 20 à 50% ☐ de 50 à 80% ☐ de 80 à 100% ☐ >100%

98. Dans quel intervalle se situe votre degré d'endettement professionnel (total dettes LMT/total passif) pour les 5 derniers exercices comptables?

Année 1	Total dettes LMT : k€ Total passif : k€ ☐ 0-9 % ☐ 30-39 % ☐ 60-69 % ☐ 90-99 % ☐ 10-19 % ☐ 40-49 % ☐ 70-79 % ☐ 20-29 % ☐ 50-59 % ☐ 80-89 %
Année 2	Total dettes LMT : k€ Total passif : k€ ☐ 0-9 % ☐ 30-39 % ☐ 60-69 % ☐ 90-99 % ☐ 10-19 % ☐ 40-49 % ☐ 70-79 % ☐ 20-29 % ☐ 50-59 % ☐ 80-89 %
Année 3	Total dettes LMT : k€ Total passif : k€ ☐ 0-9 % ☐ 30-39 % ☐ 60-69 % ☐ 90-99 % ☐ 10-19 % ☐ 40-49 % ☐ 70-79 % ☐ 20-29 % ☐ 50-59 % ☐ 80-89 %
Année 4	Total dettes LMT : k€ Total passif : k€ ☐ 0-9 % ☐ 30-39 % ☐ 60-69 % ☐ 90-99 % ☐ 10-19 % ☐ 40-49 % ☐ 70-79 % ☐ 20-29 % ☐ 50-59 % ☐ 80-89 %
Année 5	Total dettes LMT : k€ Total passif : k€ ☐ 0-9 % ☐ 30-39 % ☐ 60-69 % ☐ 90-99 % ☐ 10-19 % ☐ 40-49 % ☐ 70-79 % ☐ 20-29 % ☐ 50-59 % ☐ 80-89 %

99. Quelles sont les charges par culture en 2009 ?

Culture	*Charges*
	€/ha
	€/ha
	€/ha
	€/ha
	€/ha
	€/ha
	€/ha
	€/ha
	€/ha

Culture	*Charges*
	€/ha
	€/ha
	€/ha
	€/ha
	€/ha
	€/ha
	€/ha
	€/ha
	€/ha

FICHE CULTURE MISCANTHUS (d'après RMT Biomasse)

Nature :

Graminée pérenne originaire d'Asie atteignant à maturité 2 à 4 m de haut. La variété utilisée est un hybride stérile. La reproduction se fait par bouturage du rhizome.

Cycle :

Plantation précoce (mars-avril). Période végétative d'avril à septembre. Au cours de l'hiver, une partie des éléments nutritifs des parties aériennes migre vers les rhizomes et les feuilles tombent au sol. **Récolte 1 fois par an, à partir de la 2e ou 3e année**, **en fin d'hiver.**
Culture semblant pouvoir être exploitée pendant **10 à 20 ans** selon les premiers travaux conduits (recherches depuis les années 80 mais peu de références disponibles sur des cultures menées jusqu'à cet âge en Europe). Au moins 15 ans sans perte de rendement. En fin de culture, la destruction des rhizomes pour remobiliser la parcelle est encore peu renseignée.

Adaptation au milieu :

Préférence pour les sols **profonds et bien alimentés en eau** (très sensible au stress hydrique de juin à septembre). Faible affinité pour les sols légers ou superficiels, et **sensibilité à l'eau stagnante**. Privilégier des **terres plutôt limono-argileuses** et éviter les parcelles d'argile hydromorphe ou crayeuses.
Peut être sensible aux **fortes gelées de printemps l'année de l'implantation seulement**.
Enracinement profond pouvant atteindre 2m.

Implantation (étape clé !) :

Préparation du sol : Sur un **sol propre** (désherbage chimique ou mécanique), puis préparation du sol **fine sur une grande profondeur** (comparable à celle de la pomme de terre).

Plantation : En mars-avril, **dès que le sol est ressuyé et que les risques de fortes gelées sont passés.** Le matériel utilisé est un fragment de rhizome. Le rhizome étant très sensible au dessèchement, il impose une **plantation rapide**. Le taux de reprise en conditions normales varie de 50 à 80%.
Deux matériels possibles : en **prestation avec une planteuse automatique** développée spécifiquement (15ha/ jour mais répartition irrégulière des plants), ou **planteuse à pomme de terre** (rendement de chantier inférieur mais plantation régulière car manuelle).

Désherbage :

Concurrence des adventices peut **fortement pénaliser** les premiers rendements.
Indispensable la 1e année (chimique ou mécanique) plusieurs fois + broyage pour couvrir le sol nu en février-mars.
A partir de la 2e ou 3e année, aucun désherbage nécessaire dans la plupart des situations (sauf implantation difficile) car effet couvrant des feuilles tombées au sol.

Fertilisation :

Aucune fertilisation azotée nécessaire **pour les 2 à 3 premières années**. **Besoins faibles les années suivantes** selon la fourniture du sol, mais aucune recommandation précise ne peut être faite pour le moment. Besoins en **phosphore et potassium** peu référencés, mais exportations **globalement faibles**.

Maladies et ravageurs :

Culture **peu sensible**. Dégâts de lapins et sangliers observés la 1[e] année. Attaques de taupins constatées dans des parcelles à risque (retournement de prairie) avec des dégâts importants.

Récolte :

Récolte en sec en fin d'hiver pour un débouché en combustion (tiges à 70-85% MS).
Deux matériels possibles : **ensileuse** ou **faucheuse+botteleuse** pour densifier un produit volumineux.
Faisabilité de cette récolte en sortie d'hiver à confirmer selon la portance de la parcelle. Intervenir de préférence sur un sol **gelé ou ressuyé**.
L'objectif est l'obtention d'un produit utilisable directement ou stockable (sous abri ou bâche) pour conservation sans séchage.

Productivité :

Le **rendement augmente au cours des premières années puis se stabilise**. Entrée en production réelle à partir de la 2[e] ou 3[e] année (10tMS/ha).
Maximum de rendement semble atteint à partir de 3 à 5 ans, selon la qualité de l'implantation : de l'ordre de 10 à 15tMS/ha (pointes à 20tMS/ ha et plus). En conditions expérimentales, on a observé en France des rendements de 7 à 12tMS/ha en conditions défavorables, et de 15 à 25tMS/ha en conditions favorables.

Impacts environnementaux :

Encore mal connus, mais pas de risque de propagation. Observation d'animaux (oiseaux, gibier) dans les parcelles en hiver. Culture peu exigeante en intrants chimiques.

Eléments économiques :

Coût de la plantation (dont rhizomes) : 3200 €/ha, subventionné à 40% minimum (aide PRN)

Conditions de vente :
En l'absence d'un marché mature pour le miscanthus, la majorité des producteurs se sont engagés dans des **contrats de production à long terme** avec un transformateur (usine de déshydratation de pulpes de betterave ou de luzerne par exemple).
On fait l'hypothèse qu'on vous propose un tel contrat, avec les caractéristiques suivantes :

- durée du contrat : 15 ans
- prestation de plantation fournie (facturée ensuite, 50% faisant l'objet d'un remboursement échelonné sur 5 ans)
- appui technique fourni
- engagement pour la totalité de la récolte des parcelles faisant l'objet du contrat
- rémunération à 70 €/tMS la 1[e] récolte (bottes pressées, stockées 6mois, puis chargées)
- les années suivantes, réévaluation du prix en fonction du marché de l'énergie notamment
- bonus/malus en fonction du taux de MS et pénalités en cas de non livraison

→ **MARGE NETTE** (si la parcelle est exploitée pendant 15 ans) : 380€/ha/an environ pour un rendement de 16t/ha « en croisière »

Analyse des préférences
vis-à-vis du risque et du temps

Nom	Prénom	Ordre des tests

Date enquête	/ /2010	Code enquêteur

TEST 1. Série 1	-Je choisis la loterie A pour les questions	1 à	.
	-Je choisis la loterie B pour les questions		à 12.

TEST 1. Série 2	-Je choisis la loterie A pour les questions	13 à	.
	-Je choisis la loterie B pour les questions		à 26.

TEST 1. Série 3	-Je choisis la loterie A pour les questions	27 à	.
	-Je choisis la loterie B pour les questions		à 33.

TEST 2. Série 1	-Je parie sur les balles	☐ orange	☐ blanches
	-Je choisis la loterie A pour les questions	1 à	.
	-Je choisis la loterie B pour les questions		à 10.

TEST 2. Série 2	-Je parie sur les balles	☐ orange	☐ blanches
	-Je choisis la loterie A pour les questions	11 à	.
	-Je choisis la loterie B pour les questions		à 20.

TEST 3. Série 1	-Je choisis l'alternative A pour les questions	1 à	.
	-Je choisis l'alternative B pour les questions		à 10.

TEST 3. Série 2	-Je choisis l'alternative A pour les questions	11 à	.
	-Je choisis l'alternative B pour les questions		à 20.

TEST 3. Série 3	-Je choisis l'alternative A pour les questions	21 à	.
	-Je choisis l'alternative B pour les questions		à 30.

TEST 3. Série 4	-Je choisis l'alternative A pour les questions	31 à	.
	-Je choisis l'alternative B pour les questions		à 40.

TEST 3. Série 5	-Je choisis l'alternative A pour les questions	41 à	.
	-Je choisis l'alternative B pour les questions		à 50.

TEST 3. Série 6	-Je choisis l'alternative A pour les questions	51 à	.
	-Je choisis l'alternative B pour les questions		à 60.

TEST 3. Série 7	-Je choisis l'alternative A pour les questions	61 à	.
	-Je choisis l'alternative B pour les questions		à 70.

TEST 3. Série 8	-Je choisis l'alternative A pour les questions	71 à	.
	-Je choisis l'alternative B pour les questions		à 80.

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Résumé

L'objectif de cette thèse est d'identifier les déterminants de l'adoption des cultures pérennes énergétiques par les agriculteurs en se concentrant sur les questions de risque et de temps. L'analyse s'appuie sur le cas du miscanthus (*Miscanthus giganteus*) et du panic érigé (*Panicum virgatum*) en France, mais est potentiellement généralisable à d'autres cultures pérennes. Les décisions publiques et privées pertinentes pour encourager le développement de ces cultures sont discutées.

Dans le premier article, nous évaluons l'impact du risque et du temps sur la surface optimale de miscanthus et de panic érigé dans une exploitation de grandes cultures de la région Centre. Nous dépassons le calcul usuel de la valeur actuelle nette en tenant compte explicitement de l'aversion au risque et aux fluctuations intertemporelles à travers les cadres de l'utilité espérée et de l'utilité actualisée. Nos résultats montrent que les deux plantes pérennes sont en moyenne moins rentables que la rotation traditionnelle colza/blé/orge. Cependant, elles peuvent être très compétitives comme cultures de diversification lorsque des contrats de production adaptés sont proposés aux agriculteurs.

Les deuxième, troisième et quatrième articles exploitent les données d'une enquête et d'une expérience réalisées auprès de 111 agriculteurs de Bourgogne ayant fait face au choix de cultiver ou non du miscanthus.

Le deuxième article décrit la production de miscanthus en Bourgogne. Nous montrons d'une part que le miscanthus est implanté majoritairement sur des parcelles marginales peu rentables pour des usages traditionnels. Nous montrons d'autre part que, même en présence de contrats à long terme, les agriculteurs perçoivent le miscanthus comme globalement moins risqué que le blé, mais restent préoccupés par des risques spécifiques à issues peu probables mais extrêmement défavorables.

Dans le troisième article, nous estimons les préférences des agriculteurs par rapport au risque à partir des données expérimentales. Nous appliquons une méthode d'estimation structurelle à un modèle de décision conforme à la théorie des perspectives. Nous passons ensuite en revue un certain nombre d'implications de ce cadre théorique pour les économistes agricoles. Nos estimations indiquent que la théorie des perspectives explique mieux nos données que la théorie standard de l'utilité espérée. Les agriculteurs sont en effet averses à la perte et déforment les probabilités de manière à donner un poids important aux événements extrêmes.

Dans le quatrième article, nous examinons la relation entre l'adoption du miscanthus et les caractéristiques des agriculteurs et des exploitations, en particulier les préférences individuelles par rapport au risque et au temps. Ces dernières sont représentées par des mesures expérimentales obtenues dans le cadre de la théorie des perspectives et de l'actualisation hyperbolique respectivement. Nos résultats suggèrent que la probabilité d'adoption du miscanthus dépend du degré d'aversion à la perte des agriculteurs et de l'ampleur avec laquelle ils déforment les probabilités. Cependant, l'impact de ces deux facteurs varie avec le type de parcelle considéré et le point de référence des agriculteurs. Par ailleurs, la probabilité d'adoption est d'autant plus forte que la proportion sur l'exploitation de terres peu rentables est élevée, et que ces terres ne sont pas déjà valorisées par une activité d'élevage.

Mots-clés : préférences des agriculteurs, innovation, modèles de décision, économie expérimentale, terres marginales, biomasse

Abstract

The objective of the thesis was to identify the determinants of the adoption of perennial energy crops by farmers, focusing on risk and time issues. The analysis is based on the case of miscanthus (*Miscanthus giganteus*) and switchgrass (*Panicum virgatum*) in France, but it is potentially generalizable to other perennial crops. Public and private decisions relevant for enhancing the development of those crops are discussed.

In the first essay, I examine the impact of risk and time on the optimal area of miscanthus and switchgrass in a typical grain farm of the *Centre* region. I go beyond the usual net present value calculation by taking into account aversion to risk and intertemporal fluctuations through the expected utility and discounted utility frameworks. I find that the two perennial crops result to be, on average, less profitable than the usual rape/wheat/barley rotation. Nevertheless, they can be highly competitive as diversification crops when appropriate contracts are offered to farmers.

The second, third and fourth essays use the data from a survey and a field experiment that I conducted on 111 French farmers from *Bourgogne* who had faced the choice of whether to grow miscanthus.

In the second essay, I describe miscanthus production in *Bourgogne*. On the one hand, I show that miscanthus is mostly grown on marginal plots where traditional land uses are unprofitable. On the other hand, I show that farmers perceive miscanthus as globally less risky than wheat, but some specific, unlikely and extremely unfavorable outcomes remain cause of concern.

In the third essay, I estimate farmers' risk preferences from the experimental dataset. I apply a structural estimation method to a prospect theory decision model. Then, I review some of the implications of this theoretical framework for agricultural economists. Our estimations show that prospect theory explains our data more fully than the standard expected utility theory. Indeed, farmers are loss averse and distort probabilities so as to overweight extreme events.

In the fourth essay, I investigate the relationship between miscanthus adoption and the characteristics of farmers and farms, in particular farmers' individual risk and time preferences. The latter are experimental measures obtained in the prospect theory and hyberbolic discounting frameworks respectively. Our results suggest that adoption probability depends on farmers' degree of loss aversion and probability weighting. However, the impact of these two factors varies with land type and farmers' reference point. In addition, the proportion of low-profitability land on the farm increases adoption probability, while the presence of cattle has the opposite effect.

Keywords: farmers' preferences, innovation, decision model, experimental economics, marginal land, biomass