TRANSDISCIPLINARY DEVELOPMENT OF AGROFORESTRY SYSTEMS

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A dissertation submitted to ETH ZURICH ¦ 2012

Diss. ETH No. 20187

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A dissertation submitted to
ETH ZURICH
for the degree of
DOCTOR OF SCIENCES

presented by

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DIPLOMA IN AGRICULTURAL SCIENCES
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born June 30th, 1974

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2012

“Auch wenn ich wüsste, dass morgen die Welt zugrunde geht,

würde ich heute noch einen Apfelbaum pflanzen.“

“Even if I knew that tomorrow the world would go to pieces,

I would still plant my apple tree.”

(Martin Luther, 1483-1546)

Massongo oral tradition:

"A man lives again

through his children,

the trees he has planted,

the words he has uttered"

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Summary

Agriculture is facing major challenges, to feed the Earth's rapidly growing population and to reduce negative environmental impacts. Agroforestry is one multifunctional option which can simultaneously provide food security and other important ecosystem services. However, trees and agroforestry practices are in a declining state in many agro-ecoregions. For example modern farmers in Switzerland have widely abandoned traditional agroforestry practices, which were popular until the 1950s. Since the 1950s, 80% percent of the trees in Swiss agricultural landscapes were felled and their number is still declining, despite the increasing availability of payments for ecosystem services.

The objectives of this transdisciplinary thesis were to identify bio-economic (theme 1) and socio-economic (theme 2) risks and opportunities in the restoration of Swiss agroforestry systems. Followed by a review of transdisciplinary success stories in the development and expansion of tree-rich agricultural landscapes in Central-Europe and the West-African Sahel (theme 3).

The first research steps in theme 1 were multistakeholder workshops and exploratory surveys of farmers' agroforestry innovations. The following classification exercise and literature review suggested a lack of local knowledge on key ecosystem services potentially provided by Swiss agroforestry. It is therefore recommended to implement the concept of ecosystem services into the agricultural knowledge system. Nevertheless, the main output of the classification was an inventory of living examples for the design of practicable and multifunctional agroforestry systems. The database can be used for extension, and was also the basis for the bio-economic assessment. The bio-physical (Yield-SAFE) and bio-economic (Farm-SAFE) model assessments indicate that compared to monoculture systems, the studied agroforestry practices were predominantly more productive (12 out of 14) and can be more profitable (68% of 56 price and direct-payment scenarios). The land equivalent ratios (LER) were in the range of 0.95 - 1.30. Major economic disadvantages and risks of the agroforestry practices were linked to the long establishment phase and commonly low tree product prices. However, the identified innovative farmer strategies, such as innovative marketing of fruits or the participation in ecological payment schemes, rendered agroforestry practices competitive compared to business as usual. Still, the unanswered question was why Swiss farmers are commonly not interested in practising agroforestry, despite the increasing availability of payments for ecosystem services.

In the second theme, a seven variables survey was developed to assess Swiss farmers' behavior, aiming to shed light on the widespread abandonment of traditional agroforestry practices. This quantitative and qualitative survey approach builds on the concept of ecosystem services and the Theory of Planned Behavior. The seven variables were: intention, socio-economic characteristics, attitudes, perceived behavioral control, ecosystem services, economic motivations and subjective norms. The survey encompassed 50 randomly selected farmers in Switzerland. Two groups of farmers were identified with regard to their intentions to practice agroforestry, one which clearly intends to maintain or adopt agroforestry (52 %) and one which opposes the adoption of agroforestry practices (48 %). Habitat ecosystem

services (both for livestock and wildlife) were the most popular potential motivations for adopting agroforestry, by both farmer groups. On the other hand, most farmers attributed low scores to the productivity and profitability items, suggesting pessimistic attitudes and low economic motivations. Additionally, the majority of farmers did not perceive payments for ecosystem services as motivation for adoption. The major differences identified between both farmer groups were of non-monetary nature, such as the significant differences in the subjective norms variable. Remarkably, only adopters concluded that practising agroforestry would have a positive impact on their reputation. Furthermore, the non-adopters attributed significantly lower scores to the perceived behavioral control variable towards managing agroforestry. This complex of factors explains why payments for ecosystem services were not more successful to change Swiss farmers' behavior. Multifunctional farming systems are more likely to be adopted when the expectations as well as the resources of local land users are holistically addressed in agricultural research and development. Hence, there is need for more transdisciplinary collaboration. To support transdisciplinary development of agroforestry in Switzerland we established, in collaboration with the local extension organisation AGRIDEA, a multistakeholder platform (www.agroforst.ch; www.agroforesterie.ch).

In the third theme, transdisciplinary success stories were reviewed, which lead to the development and expansion of productive and tree-rich agricultural landscapes. One is the "Streuobst" (intercropped orchard) success story in Europe, between the 1850s and the 1950s. The second is the Sahelian alternative "Green Revolution" in the savannah parklands of West Africa, which is ongoing. The case studies imply various scientific, technical and institutional innovations, and carry three important lessons. We need to: (i) co-produce visions, knowledge and technologies in realizing synergies among limited landscape resources; (ii) create market opportunities for ecosystem goods and services and (iii) empower sustainable policies and community based governance of multifunctional landscapes. The case studies demonstrate how transdisciplinary collaboration, among a wide range of scientific and real world stakeholders, can lead to widespread landscape improvement and positive change.

Zusammenfassung

Die Landwirtschaft steht vor grossen Herausforderungen, um die wachsende Weltbevölkerung zu ernähren und gleichzeitig Umweltschäden zu reduzieren. Agroforstwirtschaft als multifunktionales System ist eine Option, um eine Balance zwischen Ernährungssicherheit und anderen Ökosystemleistungen zu erreichen. Doch gehen die Anzahl Bäume und Agroforstsysteme in vielen Agrarlandschaften zurück. So hat zum Beispiel ein Grossteil der Schweizer Bauern traditionelle Agroforstsysteme bereits aufgegeben. Bis in die 1950er Jahre war die Agroforstwirtschaft populär, seither hat die Modernisierung der Landwirtschaft zu einen Rückgang der Hochstammbäume um über 80% geführt. Diese Abnahme konnte trotz der Neuorientierung der Agrarpolitik gegen Ende des 20. Jahrhunderts und steigender ökologischer Direktzahlungen nicht aufgehalten werden.

Das Ziel dieser transdisziplinären Doktorarbeit war die Erforschung von bio-ökonomischen (Thema1) und sozio-ökonomischen (Thema 2) Zusammenhängen im Kontext der Entwicklung von multifunktionalen Agroforstsystemen in der Schweiz. Das Ziel von Thema 3 war die Ableitung von Erfolgsfaktoren aus Fallstudien über transdisziplinäre Erfolgsgeschichten aus Zentraleuropa und dem Westafrikanischen Sahel, wo die Entwicklung von baumreichen Agrarlandschaften gelungen ist.

Zum ersten Thema wurden Multistakeholder Workshops und explorative Interviews mit innovativen Bauern durchgeführt, um eine Übersicht über das lokale Wissen und die Erwartungen zu erhalten. Die anschliessende Klassifizierung ergab, dass wichtige Ökosystemleistungen heutiger Agroforstsysteme kaum systematisch erfasst worden sind. Das Hauptprodukt der Klassifizierung waren lebende Beispiele von praktikablen und multifunktionalen Agroforstsystemen. Die Datenbasis kann für die Beratung interessierter Landwirte dienen und war die Grundlage für die bio-ökonomische Modellierung. Die bio-physikalische (YIELD-SAFE Model) Modellierung ergab, dass – im Vergleich zur rein ackerbaulichen Nutzung – die untersuchten Agroforstsysteme mehrheitlich produktiver waren (12 von 14 Optionen), mit einem LER (Land Equivalent Ratio) zwischen 0,95 und 1,30. Die ökonomische (FARM-SAFE) Modellierung ergab, dass 68 % der 56 Szenarien profitabler waren als reiner Ackerbau. Die ökonomischen Nachteile der Agroforstwirtschaft waren die lange Aufbauphase und die zumeist niedrigen Preise für die Früchte von Hochstammbäumen. Die innovativen Strategien der Landwirte, wie die alternative Vermarktung von Hochstammprodukten oder die Teilnahme an ökologischen Direktzahlungs-Programmen, zeigten, dass Agroforstwirtschaft profitabel sein kann. Die Frage, warum heutzutage Schweizer Bauern, trotz der steigenden ökologischen Direktzahlungen, nicht an Agroforstwirtschaft interessiert sind blieb unbeantwortet.

Im zweiten Thema wurde ein Befragungsansatz entwickelt, um die Gründe für die fortlaufende Aufgabe von Agroforstsystemen gesamtheitlich zu erforschen. Der quantitative und qualitative Befragungsansatz beinhaltet ökonomische, ökologische (Konzept der Ökosystemleistungen) sowie psychologische (Theorie des geplanten Verhaltens) Variablen. Die sieben Variablen waren: Verhaltensabsicht, sozio-ökonomische Eigenschaften, Einstellungen, Erwartungen, Ökosystemleistungen, ökonomische Motivation, und soziale

Normen. Daraufhin wurde ein Interview mit 50 zufällig ausgesuchten Landwirten in der Schweiz durchgeführt. Zwei Gruppen von Landwirten wurden identifiziert: Befürworter (52%) und Gegner (48%) der Bewirtschaftung von Agroforstsystemen auf ihren landwirtschaftlichen Flächen. Die populärsten Motivationen (beider Bauerngruppen) waren die Habitat-Ökosystemleistungen, sowohl für die Biodiversität als auch für die Nutztiere. Im Gegensatz dazu, empfanden beide Bauerngruppen Agroforstwirtschaft als unproduktiv und unwirtschaftlich. Zusätzlich sahen die meisten Landwirte ökologische Direktzahlungen nicht als Motivation für eine Akzeptanz. Die Hauptunterschiede zwischen den beiden Bauerngruppen waren nicht-monetärer Natur, wie z.B. die signifikanten Unterschiede in der Variable soziale Normen. Interessanterweise waren nur die Befürworter davon überzeugt, dass die Bewirtschaftung von Agroforstsystemen zu einem Vorteil für das Ansehen führt. Des weiteren hatten die Gegner pessimistische Erwartungen bezüglich ihrer Fähigkeiten, Agroforstsysteme erfolgreich zu bewirtschaften. Diese Zusammenhänge können eine Erklärung dafür sein, warum die ökologischen Direktzahlungen noch keine grundsätzliche Verhaltensänderung der Landwirte bewirkt haben. Ein Wandel zur multifunktionalen Landwirtschaft wird von den Landwirten eher akzeptiert werden, wenn die Erwartungen und die Ressourcen der Landwirte gesamtheitlich betrachtet und gefördert werden. Eine transdisziplinäre Koproduktion von Wissen kann einen Beitrag dazu leisten. Mit diesem Ziel haben wir, zusammen mit AGRIDEA, eine Interessengemeinschaft Agroforst (www.agroforst.ch) gegründet.

Das dritte Thema basiert auf zwei transdisziplinäre Fallstudien. Diese sind einerseits die „Streuobst“ Erfolgsgeschichte in Zentraleuropa, welche zwischen 1850 und 1950 zu einer grossräumigen Blüte von Agroforstsystemen und Hochstammbäumen führte. Andererseits wurde die „Alternative Grüne Revolution“ in der Savannenlandschaft der West-Afrikanischen Sahelzone näher betrachtet, welche sich seit den 1980er Jahren auf dem Weg zur vollen Blüte befindet. Beide Erfolgsgeschichten zeigen die Notwendigkeit einer Vielzahl von wissenschaftlichen, technischen und institutionellen Innovationen. Drei Komplexe und zusammenhängende Lehren wurden gewonnen. Es besteht Bedarf an der: (i) Koproduktion von Visionen, Wissen und Technologien, zur Realisierung von Synergien in der Nutzung begrenzter Landschaftsressourcen; (ii) Entwicklung von Vermarktungsmöglichkeiten für materielle und nicht-materielle Ökosystemleistungen und iii) Ermächtigung von nachhaltiger Ressourcenpolitik und kommunaler Agrarlandschaftsentwicklung. Beide Fallstudien demonstrieren wie transdisziplinäre Kooperation, zwischen Wissenschaftlern und lokalen Interessengruppen, zu einer weiträumigen Landschaftsentwicklung und positivem Wandel führen kann.

Résumé

L'agriculture doit faire face à de nombreux défis pour nourrir la population mondiale qui ne cesse de croître et pour réduire les impacts négatifs sur l'environnement. L'agroforesterie est une option multifonctionnelle pour trouver un équilibre entre la sécurité de l'approvisionnement et les performances des écosystèmes. Toutefois, les arbres et les pratiques agroforestières sont en déclin dans de nombreuses régions agricoles. Les agriculteurs modernes en Suisse par exemple ont largement abandonné les pratiques agroforestières traditionnelles, en vogue jusque dans les années 1950. Depuis lors, 80% des arbres qui ponctuaient le paysage agricole suisse ont été abattus et leur nombre continue de diminuer, en dépit du montant croissant des paiements directs pour les prestations des écosystèmes.

Le but de cette thèse transdisciplinaire était d'explorer les enjeux bio-économiques (Thème 1) et socio-économiques (Thème 1) dans la perspective de réhabiliter les pratiques agroforestières multifonctionnelles en Suisse. Le troisième thème 3 était de passer en revue les projets transdisciplinaires réussis de développement et d'expansion de paysages agricoles riches en arbres, en s'attachant tout particulièrement aux études de cas en Europe centrale et dans le Sahel ouest-africain.

La recherche pour le premier thème a débuté par des ateliers réunissant plusieurs parties prenantes et par des enquêtes sur les innovations agroforestières des agriculteurs afin d'avoir une vue d'ensemble des connaissances locales et des attentes. L'exercice de classification qui a suivi et la revue de la littérature disponible ont mis en évidence qu'il y avait un manque de connaissances locales sur les prestations clés que pouvaient fournir les écosystèmes dans l'agroforesterie suisse. C'est pourquoi il est recommandé d'intégrer le concept de prestations des écosystèmes dans le système de connaissances agricoles. Toutefois, l'enjeu principal de l'enquête et de la classification était d'inventorier les exemples vivants afin de concevoir des systèmes agroforestiers multifonctionnels et praticables. La base de données peut être étendue et a également servi à l'évaluation bioéconomique.

Les évaluations biophysiques (Yield-SAFE) et bio-économiques (Farm-SAFE) indiquent que par rapport aux systèmes monoculturaux, les pratiques agroforestières étudiées étaient largement plus productives (12 sur 14) et qu'elles pouvaient être plus rentables (68% sur 56 scénarios de prix et de paiements directs). Les land equivalent ratios (LER) se situaient dans le fourchette de 0.95 - 1.30. Les principaux inconvénients et risques économiques des pratiques agroforestières étaient liés à la longue durée de la mise en place et aux prix généralement bas du produit des arbres. Cependant la politique novatrice de marketing permettant d'écouler les fruits à des prix au-dessus de la moyenne ou la participation à des programmes de paiements écologiques rentables ont rendu les pratiques agroforestières compétitives par rapport aux pratiques habituelles. Il n'en restait pas moins à savoir pourquoi les agriculteurs suisses refusaient à s'engager dans cette voie, en dépit de la promesse de paiements écologiques rentables.

Dans le second thème, une enquête à sept variables a été organisée pour faire le point sur le comportement des agriculteurs suisses, afin de comprendre les raisons de l'abandon

important des pratiques agroforestières traditionnelles. L'enquête quantitative et qualitative, basée sur le concept des prestations des écosystèmes et sur la théorie du comportement prévu, incluait 50 agriculteurs sélectionnés au hasard en Suisse. Deux groupes d'agriculteurs ont été identifiés en fonction de leurs intentions par rapport à l'agroforesterie. L'un des groupes avait l'intention de maintenir ou de s'engager dans l'agroforesterie (52 %) tandis que l'autre s'opposait à l'adoption de pratiques agroforestières (48 %). Les prestations de l'écosystème pour l'habitat (du bétail comme du biodiversité) étaient les motivations les plus populaires pour adopter l'agroforesterie dans les deux groupes d'agriculteurs. D'un autre côté, les facteurs de productivité et de rentabilité, qui faisaient partie des variables de l'enquête, ont obtenu des résultats faibles, suggérant que les deux groupes d'agriculteurs avaient une vision pessimiste des potentiels de cette branche. De plus, les deux groupes ne concevaient pas les paiements attribués aux prestations des écosystèmes comme motivants pour se lancer dans cette voie. Les principales différences identifiées entre les deux groupes d'agriculteurs n'étaient pas de nature financière, ainsi que le montrent les disparités significatives sur le critère de la réputation. Il est frappant de constater que seuls les agriculteurs partisans de l'agroforesterie ont conclu que la pratique de l'agroforesterie pourrait avoir un impact positif sur leur réputation. En outre, ces derniers ont attribué des notes nettement plus basses à la variable « contrôle du comportement perçu » dans la perspective de la gestion de l'agroforesterie. Ce complexe de facteurs explique pourquoi les paiements attribués aux prestations des écosystèmes n'ont pas contribué davantage à changer le comportement des agriculteurs suisses. Les systèmes agricoles multifonctionnels ont plus de chance d'être adoptés lorsque les attentes et les ressources des agriculteurs locaux sont abordées de façon holistique. Toutefois, il est nécessaire d'augmenter la coproduction transdisciplinaire de connaissances agro-écologiques. Pour ca une communauté d'intérêts a été créée (www.agroforesterie.ch).

Dans le troisième thème, il s'agissait de passer en revue des projets transdisciplinaires réussis qui avaient conduit au développement et à l'expansion des paysages agricoles productifs et riches en arbres. L'un d'eux est le projet "Streuobst" (verger et grandes cultures combinées) réalisé en Europe entre les années 1850 et 1950. Le second est la « révolution verte » du Sahel en cours actuellement dans les savanes d'Afrique de l'Ouest. Les études de cas permettent de tirer trois transdisciplinaires leçons, importantes pour l'amélioration des paysages riches en fruits. Il faut: i) coproduire du vision, savoir et des technologies, pour exploiter les synergies sur utiliser les ressources limitées; ii) créer des opportunités commerciales pour les produits et prestations des écosystèmes et iii) autoriser les politiques durables et la gestion locale des paysages multifonctionnels. Les études de cas démontrent que la collaboration transdisciplinaire entre les parties prenantes scientifiques et non scientifiques peut conduire à transformer le paysage et amener des changements positifs.

1 General introduction

With regard to the actual disturbances in the ecological economic system, there is increasing awareness that business as usual is no longer an option (MEA, 2005; IAASDT, 2009). Thus, a wide range of visions and solutions towards a desirable ecological and economic transition were already developed in the 20th century (e.g., Constanza et al., 1997; UN, 1992). Still, there is a lack of implementation, such as the incorporation and valuation of ecosystem services in mainstream economies (Radermacher, 2002; Daily and Ellison, 2002; IAASDT, 2009). Hence, the available concepts and solutions are either not known or not shared by key stakeholders due to competing claims. How can science enhance the quality of stakeholder negotiations towards positive change of policies and practices? Transdisciplinary research is one promising approach, which can facilitate the co-production of knowledge and the identification of shared solutions (Scholz, 2001; Hirsch Hadorn et al., 2008; Aeberhard and Rist, 2009; Eksvärd, 2010).

The focus of this thesis is on agroecosystem management, which is one of the major challenges within the overall ecological economic crisis. With regard to the ongoing efforts to rehabilitate multifunctional agroforestry systems worldwide (Palang and Fry, 2003; Eichhorn et al., 2006; Gibbons et al., 2008), the aim of this thesis is to explore possible scenarios for the revitalization of agroforestry systems. With particular emphasis on the current challenges to restore agroforestry practices in Switzerland. A transdisciplinary approach is applied with the aim to explore interlinked social, economic and ecological drivers of farmers' behavior. For example, farmers would rather not invest in the natural capital in the presence of discouraging direct-payment policies. Therefore, the increasing role of payments for ecosystem services in agro-environmental policies is promising. However, "a great unanswered question is whether the drive for profits, which has done so much harm to the planet, can possibly be harnessed to save it?" (Daily and Ellison, 2002).

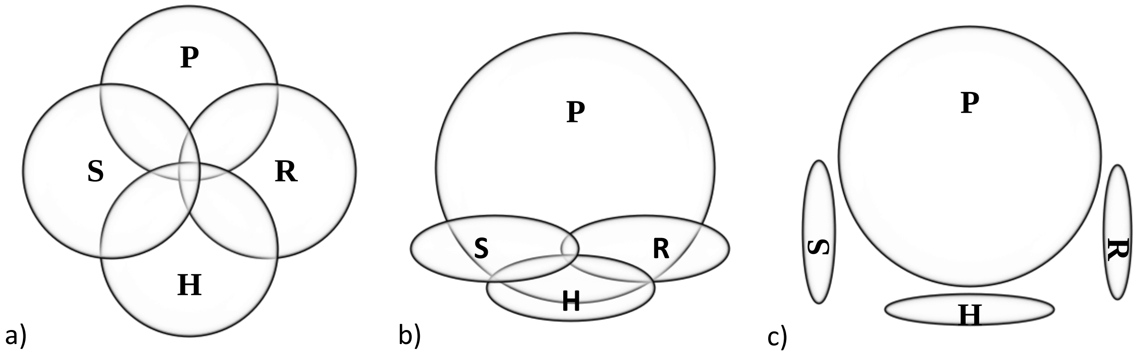
1.1 Competing views on agroecosystem management

Agriculture is facing major challenges, to feed the Earth's rapidly growing population, to reduce negative environmental impacts and to conserve biodiversity (Conway, 1997; IAASDT, 2009). While there is a common agreement on this fact, there is a wide range of perceptions on how to manage agroecosystems to achieve food security.

Two major approaches towards agroecosystem management are the agro-industrial approach and the agroecological approach (Altieri and Toledo, 2011). The agro-industrial approach includes large-scale monocultures and the application of agrochemicals and transgenic crops. The agroecological approach consists of rather small-scale, diversified farming systems, targeting ecological intensification and low external input. The followers of the first approach argue that we have to maximise agricultural yields by any technological means necessary to ensure food security. The followers of the second approach believe that the environmental and human health impacts of agro-industrial approaches are unsustainable and too expensive for poor farmers (IAASDT, 2009; de Schutter, 2010; Altieri and Toledo, 2011).

Despite these competing perceptions, it is known that agroecosystem management is a complex issue including production, habitat, regulation and socio-cultural ecosystem services (McAdam, 2009). With population growth, strategies were developed to increase the food production function of natural ecosystems. With reference to the more balanced composition of ecosystem services in natural ecosystems (Figure 1a), the potential effect of agroecosystem management on the quantity and synergistic quality of ecosystem services is illustrated in Figure 1b and 1c. Increase of food production can be achieved through biodiverse agroecological approaches such as agroforestry (1b). The development of agroforestry evolved through mimicking the function and features of the natural ecosystems in specific bio-geographic regions (Lefroy et al. 1999). Biodiverse landscape mosaics were designed with various tree and crop species and varieties, to promote diet diversity and ecological resilience. This approach facilitated the realization of synergies among ecosystem services, i.e. among the demands of particular communities. Whereas, the sole focus on the production ecosystem service leaded to widespread expansion of simplified agroecosystems (agro-industrial approach). As a result other ecosystem services (habitat, regulation and socio-cultural functions) declined (1c), due to a lack of integration (McAdam, 2009).

A balance among the agroecological and agro-industrial approach is needed to achieve food security. However, it seems that collaboration or at least co-existence of the two systems has been hardly realized, but rather competition over limited political, social and natural capitals. In the following section the conflict among the spread of agro-industrial monocultures and the decline of biodiverse agroforests in European landscapes is described.



Ecosystem services: P (Production), R (Regulation), H (Habitat), S (Socio-cultural)

Figure 1.1: Level of synergies among ecosystem services and the effect of ecosystem management. a) Natural dynamic balance, natural ecosystems as reference and starting point; b) man-made dynamic balance, multifunctional, mimicking features and functions of natural ecosystems (e.g. agroforestry); and c) man-made simplification, such as monocultural production systems, which can lead to the decline of ecosystem services.

1.2 Swiss agroforestry

Farmers have developed agroforests since ancient times, across tropical and temperate agro-ecoregions (Nair, 1993). Agroforestry can be defined as “land-use systems and technologies where woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately used on the same land management unit as agricultural crops and/or animals, either in some form of spatial arrangement or temporal sequence. In agroforestry systems, there are both ecological and economic interactions between the different components” (Lundgren & Raintree, 1982). In temperate regions fruit and timber trees as well as hedgerows were combined with arable intercrops (silvoarable systems) or with pastures (silvopastoral systems) (Herzog, 1998; Eichhorn et al., 2006).

The integrated management of tree, crop and animal biodiversity contributed to the creation of diverse cultural landscapes and the realization of synergistic advantages. Agroforestry can combine high productivity and food security with other ecosystem services (Palma et al., 2007b). Such ecosystem services include habitat (McAdam, 2007; Reeg et al., 2009; Kaeser, 2010), climate regulation through CO_2 sequestration (Montagnini and Nair, 2004; Palma, et al., 2007a; Briner et al., 2011) and soil and groundwater protection (Lehmann et al., 1999; Palma, et al., 2007a). Trees on farmland are not only important as habitat for wildlife, but create also highly attractive cultural landscapes for humans (Schüpbach et al., 2009).

However, there was a shift of agricultural policy in the 20th century. The aim was to increase agricultural productivity through high-input technologies and ecologically simplified agroecosystems. Most of the standard trees and hedgerows in many European landscapes were removed to allow efficient management of larger fields (Eichhorn et al., 2006). Public direct-payment systems discouraged the maintenance of farm trees due to ineligibility for direct-payments. Similarly, agroforestry research and development were critically neglected in Europe since the 1950s (Eichhorn et al., 2006; Herzog and Sereke, 2011). Nevertheless, food production was successfully increased, mostly in high-income-countries, but with high environmental and social costs (Conway and Pretty, 1991).

In Switzerland, for example, agroforestry was popular and widespread until the 1950s (Ewald and Klaus, 2010). But it was discouraged by the agricultural policy in the following decades, which lead to an 80% decline of trees in agricultural landscapes until 2001 (Figure 2), and their number is still declining (BLW, 2011). Finally, unacceptable environmental impacts and overproduction of crops and livestock forced policy to move back towards multifunctional agriculture. A national vote in 1996 revealed, that the Swiss public clearly (78%) demanded a transition towards integrated farming systems and multifunctional agricultural landscapes. Consequently, payments for ecosystem services were introduced to motivate farmers to re-integrate biodiversity and to decrease external inputs. To motivate the re-integration of trees into Swiss agricultural landscapes ecological payments have more than tripled in the past years, from initially 15 CHF/tree/y to 50 CHF/tree/y. Still, despite increasing payments for ecosystems services, farmers seem not to be convinced and trees and hedges in agricultural landscapes are still declining. This trend is also being experienced in other European countries (Eichhorn et al., 2006; Smith, 2010).

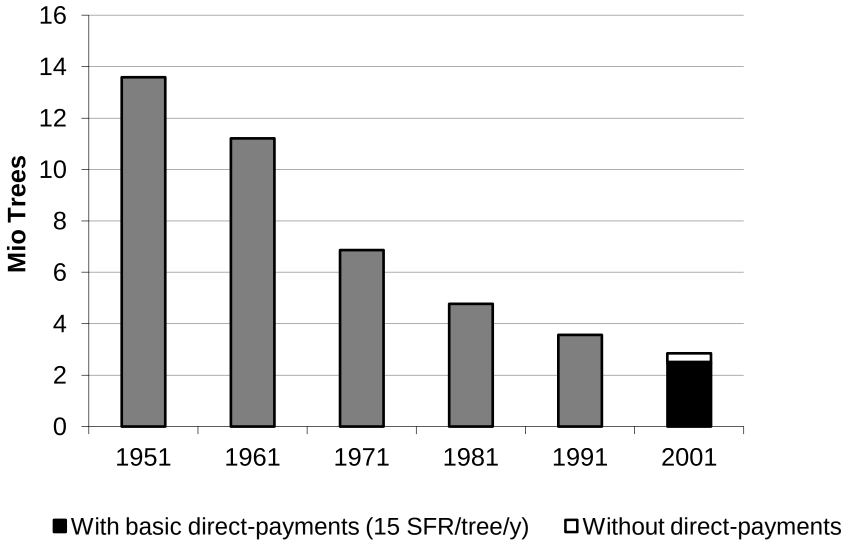


Figure 1.2: N° of standard fruit trees in Swiss agricultural landscapes declined between 1951 and 2001 (BFS, 1951-2001; BLW, 2011). In 2001 most trees were registered for the basic direct-payment scheme (15 CHF/tree/y).

1.3 Transdisciplinary assessment of agroecosystem management

The systems-oriented approach of this thesis aims at capturing the relationships among ecological, social and economic systems. The main challenge is how to assess the multidimensional driving factors of farmers' agroecosystem management?

Transdisciplinarity is a holistic methodology to facilitate sustainable transitions (Scholz, 2001). Transdisciplinary research aims at understanding various levels of reality guided by various types of logic. Through synergistic learning among scientific stakeholders with their theoretical abstract knowledge and real world stakeholders with more contextual knowledge. The objective is co-developing knowledge to more efficiently address real world challenges. This approach improves the likelihood that synergies are identified and translated into realizing win-win solutions for example in ecosystem management (Figure 1). The challenge is the 'application of ecological science to the study, design and management of sustainable agroecosystems' (Altieri, 2002). Today, science is dominated by rather isolated disciplinary research (Costanza, 2001), and the "research-policy-practice" link remains underdeveloped (Eksvärd, 2010). "The challenge is how best to mobilise specialised talent within a framework that is greater than the sum of the parts" (Cutler et al., 2009). The particular task in the transition towards sustainable agriculture is how to incorporate ecological knowledge into the well established agro-industrial knowledge system.

In the case of agroforestry, once trees are uprooted they need a long time to be restored, bio-physically and economically but also socio-culturally. Those farmers that have conversed to the "agro-industrial model have modified their system so profoundly (i.e. adopted specialized monocultures with hybrids of high energy and input dependence) that a reconversion to agroecological management may prove very difficult or impossible" (Altieri and Toledo, 2011). Despite these challenges there are also opportunities for modern farmers.

Agroforestry is an approach towards multifunctional landscapes which not only promotes desirable habitat for wildlife and humans on the landscape level, but also provides regulation functions to keep food production sustainable. The loss of biodiversity, in the agro-industrial farming systems, was linked to a loss of biological regulation functions, such as the restoration of soil fertility and pest regulation (Altieri, 1999), or pollination (Ghazoul, 2007; Kremen et al., 2007). The reduced stability of the agroecosystems increased the dependence on external inputs.

Therefore, beside the production component, farmers need a holistic picture of the ecosystem services provided by agroforestry. Hence, the ecosystem services concept is used as a framework in the following assessment exercises (Constanza et al., 1997; Daily, 1997). The objective of the ecosystem services concept is to incorporate ecosystem services into mainstream economies.

1.4 Research objectives

The main objectives of this transdisciplinary thesis were to explore bio-economic and socio-economic benefits and risks, with regard to rehabilitating multifunctional agroforests in Switzerland. The main target region for theme 1 and 2 was the Swiss central lowland region (Swiss plateau), where the greatest loss of farm trees and biodiversity has been observed in Switzerland, due to intensive agricultural practices (BLW, 2011). The research activities, conducted in the years 2007-2010, included bio-economic assessments of Swiss farmers' agroforestry innovations (theme 1) and a seven variables survey on Swiss farmers' behavior (theme 2). Theme 3 moves from assessment to implementation and reviews transdisciplinary success stories from Central-Europe and the West-African Sahel.

The project was accompanied by a group of local stakeholders and experts (such as farmers, foresters, policymakers, environmentalists and researchers). Furthermore, workshops for interested farmers were regularly conducted to exchange knowledge about agroforestry. Finally, a national multistakeholder platform was established for joint learning and collective action, which is still functional (www.agroforst.ch). The following three research questions and themes are addressed in this thesis:

Theme 1: Can agroforestry offer productive and profitable alternatives for modern agriculture in Switzerland?

The objective of theme 1 was to classify and assess different agroforestry design options and to assess their productivity and profitability. The results can provide estimations for both, interested land users who plan to adopt agroforestry practices as well as for policymakers to assess the impact of current direct-payment system.

Theme 2: Which variables explain Swiss farmers' behavior with regard to adopting agroforestry?

The objective of this chapter is to understand Swiss farmers' behavior, in order to identify potential opportunities and risks in adopting agroforestry. This information is useful in the ongoing extension efforts to restore multifunctional agro-ecosystems in Switzerland.

Theme 3: What are the success factors in transdisciplinary development of tree-rich agroecosystems?

The third objective was to review transdisciplinary success stories in the development and expansion of tree-rich agricultural landscapes, focusing on case studies from Central-Europe and the West-African Sahel. To identify important factors for successful landscape improvement, and to suggest a more positive view despite major ecological and economic uncertainties.

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2 Classification and bio-economic assessment of farmers‘ agroforestry innovations in Switzerland

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Submitted to *Agronomy for Sustainable Development*

Abstract

The process of agricultural modernisation in the second half of the 20th century resulted in a decline of trees in agricultural landscapes throughout Europe. At the same time, the neglect of agroforestry research and development resulted in a loss of knowledge on how to successfully manage agroforestry practices. For example, in Switzerland today, most farmers doubt that agroforestry can be practical, productive, or profitable. This study explores the issues of productivity and profitability in Swiss agroforestry practices, by incorporating local innovation and scientific understanding of agroforestry systems.

First, an exploratory survey of farmers' innovations together with a literature review was conducted to develop an inventory of features and functions of farmers' agroforestry innovations. The results suggested that there was a lack of local knowledge on key ecosystem services potentially provided by Swiss agroforestry systems. It is therefore recommended to incorporate the concept of ecosystem services into the agricultural knowledge and economic system. However, the main output of the classification exercise was an inventory of living examples for the design of practicable and multifunctional agroforestry systems.

Based on these results 14 representative agroforestry practices were defined for the bio-economic assessment, focusing on Walnut (*Juglans hybr.*) and wild cherry (*Prunus avium*). The bio-physical predictions of the long-term yields (Yield-SAFE model), indicated that agroforestry practices were commonly more productive (12 out of the 14 options) than the monoculture reference, with land equivalent ratios (LER) in the range of 0.95 - 1.30. In 68% of the 56 financial scenarios (Farm-SAFE model) agroforestry practices were found to be more profitable than business as usual monoculture. The main disadvantages and risks of the agroforestry practices were connected to the long establishment phase and low average fruit prices. Nevertheless, the innovative marketing of tree products and/or payments available for ecosystem services made the agroforestry practices economically competitive.

Keywords: Agro-environmental policy, ecosystem services, participatory research

2.1 Introduction

For much of human agricultural history, trees in agricultural landscapes have been used to provide a range of ecosystem services including physical products. However, agriculture has changed enormously in the second half of the last century, driven by agricultural policy and technological progress. The trees that characterised many temperate agro-ecosystems across the globe have been lost to a large extent (Palang and Fry, 2003; Kumar and Nair, 2006).

For much of their history, Swiss landscapes have also been characterized by agroforestry practices (Stuber and Burgi, 2001, 2002; Burgi and Stuber, 2003). Silvopastoral and silvoarable practices, called “Streuobst”, which peaked in the 1950s, have, as in other European landscapes, declined drastically. The post war policy of agricultural modernization discouraged the continued maintenance of trees on agricultural land, and actively financed their felling (Herzog, 1998; Ewald and Klaus, 2010). Consequently, of the approximately 14 million trees standing in agricultural land in Switzerland in 1951, only 2.9 million trees were left in 2001, a reduction of 80% (BFS, 2001). Whilst it is generally recognized that during this period, agricultural production has increased, there has also been a general impoverishment in the provision of ecosystem services that benefit society, namely habitat, regulation, and cultural ecosystem services (McAdam, 2009).

A national vote in 1996 showed that 78% of the Swiss public would support a transition back towards low input and multifunctional agricultural landscapes. Consequently, in recent years, agricultural policy has increasingly made efforts to reduce agricultural externalities and improve the provision of ecosystem services. In this regard, a major challenge is the development of innovative farming systems, which can meet the demand for multifunctional service provision whilst remaining productive and profitable.

Whilst tropical agroforestry research has enjoyed much attention (www.icraf.org), it is only recently that temperate agroforestry research has gained some momentum. As part of this, experimental plots have been established on research stations in a number of European countries and these results have been instrumental in the development of agroforestry models that can simulate tree and crop interactions (Van der Werf et al., 2007; Graves et al., 2010). Such simulation models have predicted that temperate agroforestry practices combining high-value timber production with crops or grassland can be more productive (yields/ha) than when grown separately as monocultures (Graves et al., 2010). Agroforestry can combine high productivity with a wide range of other ecosystem services (Palma et al., 2007; Reeg et al., 2009; Kaeser, 2010; Briner et al., 2011). Furthermore, trees in agricultural landscapes are popular (Schüpbach, 2009).

Despite the revival of research interest, and increasing direct-payments for the maintenance of agroforestry practices, the decline of farm trees and hedgerows is still on-going in many European landscapes (Eichhorn et al., 2006). One way of increasing the adoption and maintenance of modern agroforestry systems is to ensure that research builds on local knowledge and cultural landscapes (Wettasinha and Waters-Bayer, 2010). Therefore, in addition to field experiments and disciplinary studies, there is a need for participatory and transdisciplinary research in close alliance with local farmers to take account of the social aspects of adopting new technologies.

Within this Swiss agroforestry project an integrated seven step survey was conducted, involving 50 randomly selected Swiss farmers, to explore their behavior with regard to adoption or non-adoption of agroforestry (Sereke et al., 2012). The results suggest that many farmers view agroforestry as difficult to manage as well as unproductive and unprofitable.

The objective of this study is to explore the productivity and profitability of Swiss agroforestry practices. Through a transdisciplinary approach building on local innovation and scientific understanding, the following questions were investigated:

1. What are the features and functions of farmers' agroforestry innovations?
2. Is Swiss agroforestry productive compared to monoculture systems?
3. Can agroforestry be economically competitive given current prices and payments for ecosystem services?

2.2 Material and methods

Methodologically, this study combined field-based research with generation of scientific evidence. The following research steps were undertaken:

1. Classification of features and functions of Swiss agroforestry practices according to McAdam et al. (2009);
2. Simulation of long-term yields of representative agroforestry practices with the Yield-SAFE model (Van der Werf et al., 2007);
3. Assessment of profitability using the Farm-SAFE model (Graves et al., 2007).

The main target region was the Swiss central lowland region (Swiss plateau), where the greatest loss of farm trees and biodiversity has been observed due to intensive agricultural practices (BAFU & BLW, 2008; Lachat et al., 2010).

2.2.1 Classification of Swiss agroforestry

The exploratory survey was conducted between 2007 and 2009. Farmers were identified at workshops and through contacts with experts. Semi-structured interviews were conducted on-farm and interviewees were either the farm owner or the manager. The questionnaire covered socio-economic, technical and agro-ecological aspects of the agroforestry practices.

For classifying the agroforestry practices we modified and applied a European classification approach (McAdam et al., 2009). The classification categories were: components, spatial and temporal arrangement, agro-ecological zone, socio-economic features and ecosystem services. Ecosystem services included production, habitat, regulation and socio-cultural benefits. Potential ecosystem services were identified on the basis of national (were available) and other European publications on temperate agroforestry.

Each agroforestry practice was described in a factsheet and a database containing social, bio-physical and economic data. These factsheets have been subsequently used for extension workshops and practice oriented publications. Based on this survey, 14 representative options were defined for the bio-economic assessment, focusing on Walnut (*Juglans hybr.*) and wild cherry (*Prunus avium*).

2.2.2 Bio-physical assessment

Due to lack of field data in Switzerland, the biophysical model Yield-SAFE (Van der Werf et al., 2007) was implemented as a spreadsheet model (Plot-SAFE) in Microsoft Excel© (Burgess et al., 2004), and used to estimate long-term crop and tree yields for a full tree rotation. In this, a series of spreadsheets were used to store tree and crop management data, soil, tree and crop parameters as well as daily weather data.

The model was calibrated for the lowland plateau in Switzerland using the following steps. Daily weather data for Zurich (solar radiation (MJ m^2), mean daily temperature, and daily precipitation (mm) were supplied by the Federal Office of Meteorology and Climatology (MeteoSwiss). The weather data showed that the area could expect an annual average precipitation of 1086 mm. With an altitude of 556 m and a geographical position (8°34' / 47°23') these are typical site conditions for the Swiss plateau. Similarly, average soil conditions were assumed with a soil depth of 100cm and medium-fine texture.

In a two stage calibration process (Burgess et al., 2004; Graves et al., 2006), the model was initially calibrated for “potential” yields of a range of monoculture crop and tree systems, which were limited by light and temperature (but not water) for the Atlantic and Mediterranean regions of Europe. Then, using these parameters for potential tree and crop growth, three parameters (management factor, harvest index, water use efficiency) were adjusted to calibrate the model against locally measured “reference” yields, but this time, under water limiting conditions.

Here, average lowland crop yields (Nemecek et al., 2005; Lips et al., 2006) were used for the reference crop calibrations, with 5.6 t ha^{-1} for winter-wheat and 3.0 t ha^{-1} for oilseed (Table 1). Average grass yields were 12.0 t ha^{-1} for high input grassland and 4.0 t ha^{-1} for low input grassland (Dux, 2009, unpublished data).

For calibrating the potential growth of wild cherry, published tree growth tables were used from the nearby and climatically similar region of South Germany (Spiecker, 1994). These data showed that a timber volume of 1.07 m^3 $tree^{-1}$ for year 60 could be achieved for forestry trees. We assumed an initial planting density of 816 trees ha^{-1}, regularly thinned to a final density of 100 trees. For walnut, the calibration for French yield data was used (Graves et al., 2007) as local data were not available. In this, the assumed tree volume was 0.99 m^3 tree-^{1} in year 60 for a walnut forestry system, planted at an initial density of 210 trees ha^{-1} and thinned twice by 55 trees.

Since the model did not include a fruit component, annual fruit yields were based on local fruit yield data, with average yields of 32 kg tree^{-1} (Maurer et al., 2008) for walnut and 41 kg tree^{-1} for wild cherry (farmers' data). The management factor, pruning height, and the tree line widths were adjusted to simulate the growth, shape and management of fruit trees in order to determine their impact on intercrop growth and yield. Generally, lower tree densities result in higher timber and fruit yields per tree, as the trees have more space to grow larger.

The relative productive advantage of the agroforestry system in comparison to growing the annual and perennial systems separately was examined using the Land Equivalent Ratio (LER). The LER has been defined by Ong (1996) as "the ratio of the area under sole cropping to the area under the agroforestry system, at the same level of management that gives an equal amount of yield".

$$\textbf{LER} = \frac{\text{Tree yield AF}}{\text{Tree yield monoculture}} + \frac{\text{Crop yield AF}}{\text{Crop yield monoculture}}$$

Where the LER is calculated to be greater than 1, then there is a productive advantage to growing trees and crops in an agroforestry system. Where the LER is less than 1, the opposite is true, and there is a productive disadvantage to growing the trees and crops in an agroforestry system. Here, more than one crop was used in the rotation and therefore a time-based proportionally weighted ratio for each crop was developed over the 60 year rotation.

2.2.3 Economic assessment

Based on the predicted yields and local economic data the profitability was calculated using the Farm-SAFE model (Graves et al., 2007). As tree planting is a long-term enterprise, future income and expenditure was discounted and aggregated to obtain the Net Present Value (NPV). This is described by Equation 1:

$$\mathrm{NPV} = \sum_{t=0}^{t=T} \frac{R_t - V_t - A_t}{(1+i)^t} \qquad \text{Equation 1}$$

Where NPV is the net present value (SFR ha^{-1}) of the monoculture or the agroforestry land use options, R_t is the profit from the enterprise (including subsidies) in year t (SFR ha^{-1}), V_t is the variable costs in year t (SFR ha^{-1}), A_t the assignable fixed costs in year t (SFR ha^{-1}), T the time horizon (years), and i is the discount rate. A discount rate of 3.5% was used, as this has been the opportunity cost of capital assumed for previous economic studies on Swiss orchards (Alder, 2007).

For the economic assessment, a database based on the field survey and published literature was established, describing local crop and tree management, costs, revenues and direct-payment regimes. The data for the arable cropping system (Lips et al., 2006) and the grassland system (Dux, 2009, not publ.) were supplied by the local research station for agricultural economics (Table 1). Regarding the grassland, we assumed prices for quality fodder to assess the value of grass yields in the silvopastoral system.

Data for walnut production were provided by the local research station for fruit production (Maurer et al., 2008), with a reference walnut fruit price of 5 SFR/kg (Table 2). Based on the field survey, a cherry fruit price of 2.75 SFR/kg was assumed. The price for high value walnut timber varies considerably, with an average price of 1168 SFR/m^3 (WVZ, 2009). The reference value recommended for high quality wild cherry timber was SFR 800/m^3 (WALDSG, 2010).

The following direct-payments were considered for the bio-economic calculations. General direct-payments are paid as flat rates for the agricultural area. For our crop rotation these were 1600 SFR/ha for wheat and oilseed rape (Lips et al., 2006), with additional crop specific payments of 204 SFR/ha for wheat and 1601 SFR/ha for oilseed rape. The grassland areas received a basic payments of 1040 SFR/ha (BLW, 2008).

The ecological direct-payments for standard trees consist of a basic payment of 15 SFR/$tree^{-1}$. Additional payments of 30 SFR/$tree^{-1}$ are available if the farmer complies with ecological quality demands, such as: tree densities between 30-100 trees/ha; trees well maintained and specific ecological quality standards met. The extra labour and material costs to meet the habitat quality criteria were considered in the NPV calculations. Hence, our direct-payment scenarios compared the basic tree direct-payments (15 SFR/$tree^{-1}$) with the accumulated ecological payments for trees (45 SFR/$tree^{-1}$).

Table 2.1: Average yields, costs and revenues of the crop component (Lips et al., 2006; Dux, 2009, not publ.)

Input category	**Unit**	**Wheat**	**Oilseed**	**Grassland**	
				high input	low input
Yield	t ha^{-1}	5,6	3,0	12,0	4,0
Product value	SFR t^{-1}	590	800	354	0
Direct costs	SFR ha^{-1}	1.182	1.462	0	0
Overhead and labour costs	SFR ha^{-1}	3.925	3.564	4.791	2.270
Product revenue	SFR ha^{-1}	3.302	2.400	4.250	0
Other revenues	SFR ha^{-1}	524	47	0	0
Area payments	SFR ha^{-1}	1.600	1.600	1.040	1.040
Specific crop payments	SFR ha^{-1}	204	1.601	0	0

Table 2.2: Yields, costs and revenues of the tree component (Maurer et al., 2008; WVZ, 2009; WALDSG, 2010). As these values are changing within the 60 year tree rotation, an example of the costs and revenues in the year 30 is presented. Depending on the agro-environmental scheme the farmer participates in, 15 or 45 SFR $tree^{-1}$ are currently available in Switzerland.

Input category	**Unit**	**Wild cherry**				**Walnut**			
		Timber		Fruits		Timber		Fruits	
	trees ha	40	70	40	70	40	70	40	70
Yield	Yield ha^{-1}	53.9 m^3	79.8 m^3	1.8 t	2.9 t	57.8 m^3	80.6 m^3	1.3 t	2.0 t
Product value	SFR	800 SFR m^3		2750 SFR t		1168 SFR m^3		5000 SFR t	
Establishment costs	SFR ha^{-1}	2.716	3.898	3.030	4.447	2.698	3.477	4.789	7.838
Maintenance costs	SFR ha^{-1}	574	917	2.462	3.992	427	521	2.318	3.511
Harvest costs	SFR ha^{-1}	114	200	900	1.450	114	200	2.860	4.400
Direct payments									
Area payments	SFR ha^{-1}	1.040	1.040	1.040	1.040	1.040	1.040	1.040	1.040
i) Common 15 SFR/$tree^{-1}$	SFR ha^{-1}	600	1.050	600	1.050	600	1.050	600	1.050
ii) Ecological 45 SFR/$tree^{-1}$	SFR ha^{-1}	1.800	3.150	1.800	3.150	1.800	3.150	1.800	3.150

2.2.4 Definition of Scenarios

The survey identified two marketing strategies followed by the farmers. The first was the product innovation strategy which aimed to increase the tree product revenue through direct marketing of innovative regional specialities. The second approach was the upcoming ecosystem services strategy where the farmers aimed to market ecosystem services through participation in the ecological direct-payment scheme. Some farmers managed to more or less combine both strategies, still they were assessed separately to analyse their specific cash flow performance. Additionally, one pessimistic price scenario was defined as low fruit prices are a main risk for the profitability of Swiss agroforestry practices (Alder, 2007). Similarly, the price of high value timber depends on the timber quality and on changing consumer trends.

Hence, the following scenarios were defined:

1. BASIC_A: Baseline scenario, with basic direct-payments (15 SFR/tree^{-1}) and average tree product prices;
2. BASIC_P: Basic direct-payments and pessimist tree product price (-10%);
3. BASIC_O: Basic direct-payments and optimist tree product price (+10%), representing the tree product innovation strategy;
4. ECO: Ecological innovation scenario, with payments for ecosystems services (45 SFR/tree^{-1}) and average tree product price.

2.3 Results and discussion

2.3.1 Classification of Swiss agroforestry

Table 2.3: Classification of Swiss agroforestry practices, modified according to McAdam et al. 2009. Site: Best plain land (B), Marginal sloping land (M). Agroforestry systems: Silvopastoral (SP), windbreak (WB), silvoarable (SA), forest grazing (FG), forest garden (FGA). Ecosystem services include Production: Fruit (P1), Timber (P2); Habitat: Biodiversity (H1), Shelter for livestock (H2); Regulation: Windbreak (R1), Soil/water conservation (R2); Socio-cultural functions (S).

ID	Location		Components				Arrangement	Ecosystem services
	Village (Canton)	Site	AF System	Local name	Main tree species	Intercrop		
SP1	Gempen (SO)	M	Silvopastoral	Streuobstwiesen	*Prunus avium*	Pasture	Mixed sparse	P1 (P2), H1, H2, S
SP2	Oberflachs (AG)	M	Silvopastoral	Streuobstwiesen	*Prunus avium, Juglans regia, Castanea sativa, Malus domestica, Pyrus communis, Prunus domestica, Cydonia oblonga*	Pasture	Mixed sparse	P1, H1, H2, S
SP3	Nendaz (VS)	M	Silvopastoral	Pré-verger	*Prunus armeniaca*	Pasture	Mixed sparse	P1, H1, H2, S
SP4	Zeiningen (AG)	M	Silvopastoral	Streuobstwiesen	*Morus alba*	Pasture	Mixed sparse	P1, H1, H2, S
SP5	Frick (AG)	M	Silvopastoral	Streuobstwiesen	*Prunus avium, Mespilus germanica, Pyrus pyraster, Rosa canina, Sorbus aucuparia, Sorbus torminalis, Sorbus domestica, Cornus mas*	Fodder	Strip planting	P1, H1, S
SP6	Truttikon (SH)	B	Silvopastoral	Streuobstwiesen	*Juglans regia*	Fodder	Strip planting	P1, H1, S
SP7	Muri (AG)	M	Silvopastoral	Streuobstwiesen	*Prunus domestica, Juglans regia, Pyrus communis, Prunus avium, Sorbus aucuparia, Castanea sativa, Malus domestica, Sorbus domestica*	Fodder	Strip planting	P1, H1, S
SP8	Steinmaur (ZH)	B	Silvopastoral	Streuobstwiesen	*Malus domestica, Prunus avium, Pyrus communis, Cydonia oblonga, Pyrus pyrifolia, Mespilus germanica*	Fodder	Strip planting	P1, H1, S
SP9	Hauptwil (SG)	M	Silvopastoral	Streuobstwiesen	*Juglans regia*	Pasture	Strip planting	P1, H1, H2, S
WB	Toggenburg (SG)	M	Windbreak	Baumhecken	*Prunus spp., Pyrus spp., Malus spp., Corylus avellana, Acer spp., Fraxinus excelsior, Sambucus nigra, Prunus padus, Prunus spinosa, Crataegus monogyna, Cornus mas*	Fodder	Boundary	P1, H1, R1, S
SA1	Möhlin (TG)	B	Silvoarable	Streuobstäcker	*Prunus avium, Malus domestica, Pyrus communis*	Arable	Strip planting	P1, H1, S, R2
SA2	Sursee (LU)	B	Silvoarable	Streuobstäcker	*Malus domestica*	Arable	Strip planting	P1, H1, S, R3
SA3	Steinmaur (ZH)	B	Silvoarable	Streuobstäcker	*Pyrus pyraster*	Arable	Strip planting	P1 (P2), H1, S, R2
FG1	Breno (TI)	M	Forest grazing	Selva	*Castanea sativa*	Pasture	Mixed sparse	P1, H1, H2, S
FG2	Arosio (TI)	M	Forest grazing	Selva	*Castanea sativa*	Pasture	Mixed sparse	P1, H1, H2, S
FG3	Brontallo (TI)	M	Forest grazing	Selva	*Castanea sativa*	Pasture	Mixed sparse	P1, H1, H2, S
FG4	Vezio (TI)	M	Forest grazing	Selva	*Castanea sativa*	Pasture	Mixed sparse	P1, H1, H2, S
FG5	Chaux-des-Breuleux (JU)	M	Forest grazing	Pâturage boisé	*Abies alba, Picea abies, Acer pseudoplatanus, Fagus sylvatica*	Pasture	Mixed sparse	P2, H1, H2, S
FG6	Bettwiesen (SG)	M	Forest grazing	Tannenweid	*Abies nordmanniana, Abies koreana, Picea pungens glauca*	Pasture	Strip planting	P2, H1, H2, S
FG7	Wildenstein (BL)	M	Forest grazing	Eichenwitwald	*Quercus robur*	Pasture	Mixed sparse	P1 (P2), H1, H2, S
FGA	Toggenburg (SG)	M	*Forest garden*	Waldgarten	*Prunus domestica, Pyrus communis, Malus domestica, Prunus domestica, Fraxinus excelsior, Acer spp., Alnus spp., Populus spp., Frangula alnus, Ulmus spp., Sorbus aucuparia, Salix spp.*	Horticulture	Successional	P1 (P2), H1, R2, S

Location and components

Our exploratory survey and literature review yielded an inventory of 21 tree-crop or tree-grass combinations (Table 3). Traditional orchards are characterised by widely spaced standard fruit trees of old varieties. They are commonly located in the lowland and hilly regions of Switzerland. In the silvopastoral group (SP1 to SP9), trees are intercropped with fodder grass which is grazed or cut for hay making. The silvoarable case (SA1 to SA3) is hardly found nowadays. There, trees are intercropped by arable crops (vegetables, winter-wheat, winter-barley, oilseed, grain maize, forage maize and sunflower).

The hedgerow or windbreak (WB) systems, described by Vogt, 1999, are typical examples of diverse landscapes of the pre-alps. However, today remnant hedgerows are often not actually part of the farm holding which may explain their neglect by farmers.

Forest grazing systems (FG1 to FG7) mainly occur in the (lower) mountainous regions. Some of these (FG1 to FG4) are revitalised traditional chestnut orchards, which mainly occur on the south facing slope of the Alps. Others (FG5 to FG6) are representative of the Jura Mountains (where Switzerland and France share borders), where free ranging cattle and horses graze in a semi-open landscape with characteristic, free standing (mostly coniferous) trees. The forest grazing practice FG7 is a 500 years old remnant of the formerly widespread oak forest grazing system, and is now protected for cultural and natural heritage. In contrast, forest grazing practice FGA is recent and aims, in the manner of a "forest garden", to mimic the features and functions of natural ecosystems with dense combinations of annual crops, shrubs and tall trees (Vogt, 1999).

These findings for Switzerland echo the situation in much of Europe, where only remnants of formerly widespread temperate agroforestry practices continue to exist in a declining state (Lucke et al., 1992; Herzog, 1998; Eichhorn et al., 2006).

Spatial and temporal arrangement

When machinery is used to cut fodder or manage crops, trees are typically arranged in strips in the fields or on the field boundary. In grazed agroforestry systems, the spatial arrangement of the trees is usually mixed and sparse. The forest garden system (FGA) was arranged in a mixed design with a successional management approach.

Ecosystem services

Production services

The interviewed farmers were generally more interested in fruit than in timber production. Timber was also produced but mainly in the forest grazing systems. The understory was also a source of revenues through arable crops or fodder production as well as through livestock products.

A promising example for product innovation was the wild cherry innovation (SP1). The farmer produces high value wild cherries for the local processing and liquor industry, whilst the intercropped pasture is mown and grazed by livestock. The walnut silvopastoral system (SP6) was another promising innovation. In both cases, farmers managed to sell their tree products at well above the average prices.

Habitat services: Biodiversity & shelter for livestock

The habitat function provided by agroforestry is the main ecosystem service scientifically recognised in Switzerland (Kaeser, 2010; Herzog 1997; Bailey et al., 2010). The flora and fauna from the following three agroforestry systems are recognised to be of potential benefit in an official inventory (BAFU & BLW, 2008). The three systems are: 1) “Streuobst” with standard fruit trees; 2) Hedges and woods along fields, as well as; 3) Forest grazing systems. Most identified agroforestry practices fall in one of these categories. In the case of silvoarable systems, there appears to be a lack of data linking the system to clear biodiversity benefits (Kaeser, 2010). With regard to shelter for livestock, obtaining this service is the main motivation why Swiss farmers plant trees (Sereke et al., 2012).

The habitat benefits of agroforestry have also been confirmed in other European studies (Burgess, 1999; McAdam et al., 2007).

Regulation services

Due to hilly and mountainous terrain in Switzerland, soil erosion causes serious problems on susceptible sites, and nitrate leaching is a major problem in high input farming systems in the lowlands (Decrem et al., 2007). Notably, no studies were found on the soil and groundwater conservation potential of agroforestry in Switzerland. However, in European studies, the potential of agroforestry to tackle these issues has been highlighted (Lehmann et al., 1999; Palma, et al., 2007). The potential of farm trees to help counter climate change by sequestering atmospheric carbon (C) in Switzerland has hardly been explored (Briner et al., 2011), whereas in Europe, studies have examined the possible role of farmland trees in this context (Montagnini and Nair, 2004; Palma, et al., 2007).

Socio-cultural services

The deep connection of Swiss people with trees is illustrated by the tradition of planting a tree for each new born child (Lurker, 1976). The tree of life park (SP7) offers this service. The price is 50 SFR-1 with a 20 year contract; afterwards the child decides how to proceed. “Streuobst” landscapes with native fruit trees and hedges are the most popular components of Swiss cultural landscapes (Schüpbach et al., 2010).

Need for implementing the ecosystem services concept

According to our review, the most recognised ecosystem service provided by agroforestry was biodiversity. Lack of local data was identified for other ecosystem services, such as soil conservation, and groundwater protection. This is linked to the general lack of implementation of the ecosystem services concept in Swiss landscape planning process. A first strategy to incorporate ecosystem services has been suggested recently, which is promising (Staub et al., 2011). Because of this, we recommend that a systematic valuation of ecosystem services in the agricultural economy is needed, which would recognise the benefits of multifunctional farming systems. The importance of valuing ecosystem services in order to incorporate the value of non-market benefits in decision-making over the environment is a matter of urgent concern and the subject of a number of international studies (e.g. Grêt-Regamey et al., 2008; Termorshuizen and Opdam, 2009; TEEB, 2010).

2.3.2 Bio-physical assessment

Definition of representative agroforestry practices

The survey yielded diverse agroforestry designs with various tree species (Table 3). In order to assess their productivity and profitability, we established a typology, focusing on *Juglans hybr.* and *Prunus avium* as two of the most popular tree species, which can be used for both, nut/fruit and timber production. Both tree species were planted by 7 and 4 surveyed farmers, respectively. Their suitability for agroforestry has been assessed in other temperate regions of Europe (Graves, 2007; Dupraz and Liagre, 2008; Reeg, 2009).

For both tree species various design options and direct-payment scenarios were assessed, following the main design strategies identified by the survey (Fig. 1).

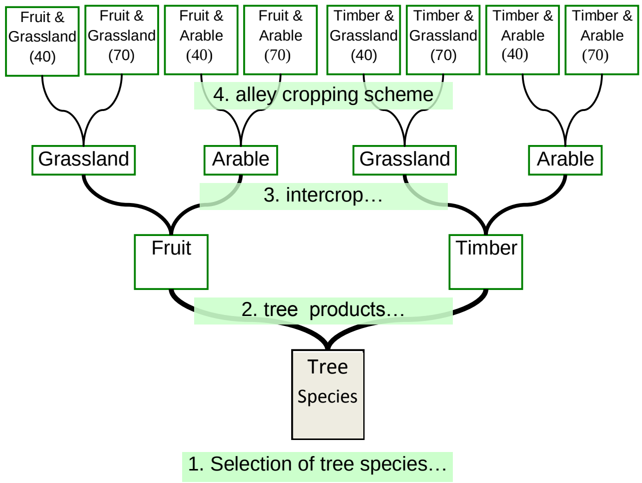

Figure 2.1: Decision tree for agroforestry design options. Two tree species were simulated (wild cherry/walnut), with two production options (fruit/timber), two types of intercropping (grassland/arable) and with 40/70 trees/ha.

According to our observations, most farmers' choice is fruit production combined with fodder production or pastures. Yet, recent agroforestry research in temperate European regions indicates that high value timber production and silvoarable agroforestry can also be profitable (Van der Werf et al., 2007; Graves, 2007; Dupraz and Liagre, 2008; Reeg, 2009). Hence, the two tree management options were considered for the assessment. The intercrop options were silvopastoral and silvoarable intercropping.

Regarding tree density, farmers planted trees in low and high densities. Therefore, low (40 trees/ha) and high density (70 trees/ha) options were defined. In mechanized agroforestry trees are planted in rows and the row distance should fit the maximum machinery width (12 m in Switzerland). We assumed a tree strip width of 2m for pruned timber trees (Graves, 2007; Dupraz and Liagre, 2008) and of 4m for fruit trees, due to their larger crowns. A tree distance within the rows of 10m was assumed, which is suitable for both production systems (Gersbach, 2003).

This results in eight alley cropping schemes for a given tree species, representing both the widespread silvopastoral and the less frequent silvoarable systems. For cherry, the combination of fruit production with arable crops was discarded, due to conflicting harvest periods. A typical crop rotation was assumed with oilseed/winter-wheat/rotational grassland/winter-wheat. The grassland was managed through a common mechanized cut and carry system, where silage bales are produced for high-quality forage.

Yield assessment

The four assessed tree-crop combinations were timber-arable (TA), fruit-arable (FA), timber-grassland (TG) and fruit-grassland (FG) with 40/70 trees/ha. Figure 2 shows 4 silvopastoral combinations with wild cherry trees and 4 silvoarable combinations with walnut trees. These examples show how the relative intercrop yields steadily declined during the 60 years cropping cycle under wild cherry (Figure 2a) and walnut trees (Figure 2c). Fruit trees had a greater impact on the intercrop than timber trees because the later are pruned to achieve long straight stems. The pruning reduces light competition and also allows a minimum tree line width (of 2m). More significantly, the high density options (70 trees/ha) had a stronger impact on the intercrop than the low density options (40 trees/ha). Under the high density conditions continuous cropping for 60 years was not feasible. Hence, according to the NPV calculations low input silvopastoralism was assumed when the profitability of high input intercropping was not profitable anymore. Similar results were found by Dupraz and Liagre (2008) who recommend a low tree density (< 50 trees/ha) if continuous intercropping is planned.

The corresponding timber (T) and fruit (F) yields are also demonstrated. For example the wild cherry system TG70 yields 79.8 m^3/ha^{-1} high value timber in year 60 (Figure 2b), whilst the walnut FA70 system yields 2.0 t/ha^{-1} of walnuts in the same year (Figure 2d).

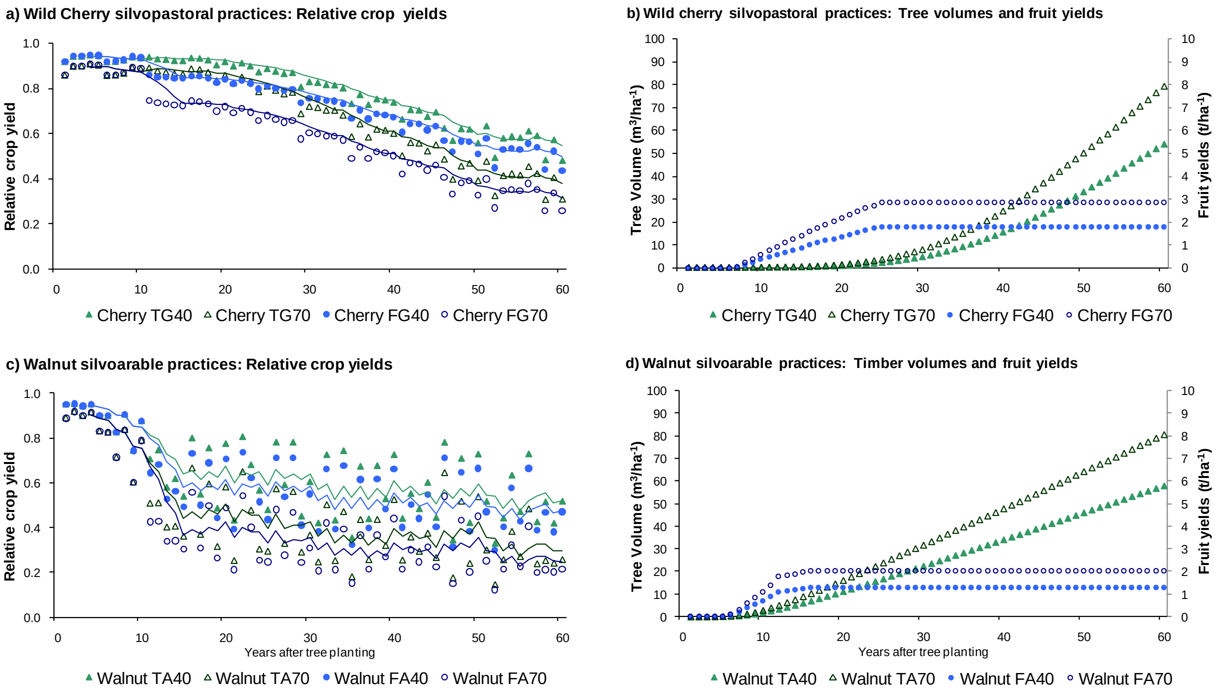

Figure 2.2: Relative crop yield developments under wild cherry silvopastoral practices (a) and walnut silvoarable practices (c). Compared to the arable (rotation: oilseed/w-wheat/rotational grassland/w-wheat) and grassland monoculture references. The silvopastoral tree-crop combinations were timber-grassland (TG) and fruit-grassland (FG) and the silvoarable combinations were timber-arable (TA) and fruit-arable (FA). The corresponding high-value timber (T) volumes (m^3/ha^{-1}) and fruit (F) yields (t/ha^{-1}) are also shown (b and d), for 2 tree densities (40 and 70 trees/ha).

Twelve of the 14 simulated agroforestry options had a land equivalent ratio higher than one, indicating that most studied agroforestry options were more productive than the respective monoculture systems (LER=1). The LER was systematically higher for the cherry systems, timber options and for high tree densities. The two practices with a LER below 1 where Walnut FG40 (0.95) and Walnut FA40 (0.99). The highest LER was achieved by the cherry options FG70, TA70 and TG70 with 1.30, 1.30 and 1.29 respectively.

The predicted LER indicate that combining tree and crop production increases the overall productivity. Higher productivity of agroforestry compared to monoculture was also found for other European countries (Graves et al., 2007). These findings contradict the average farmer's view that agroforestry is less productive than monoculture (Sereke et al., 2012).

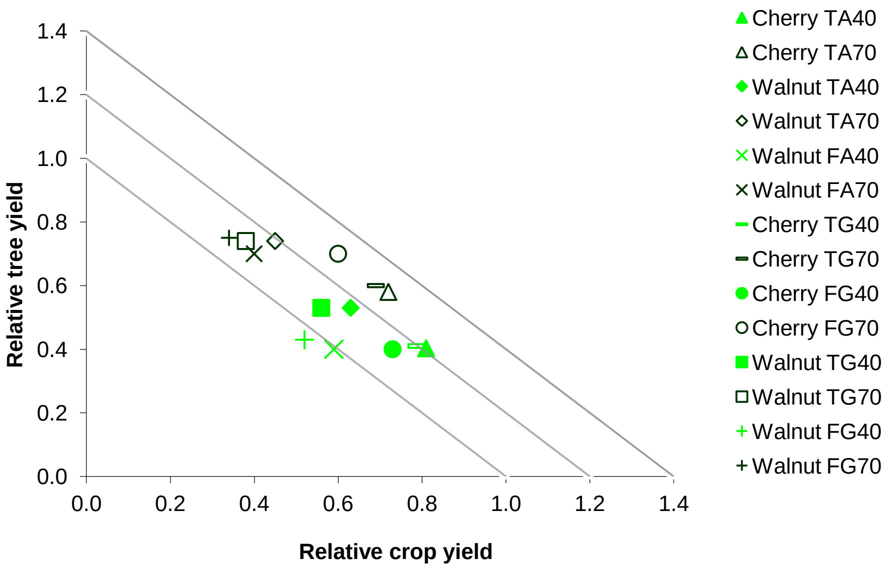

Figure 2.3: Land equivalent ratio (LER) for the wild cherry and walnut based agroforestry practices. For the tree-crop combinations timber-arable (TA), fruit-arable (FA), timber-grassland (TG) and fruit-grassland (FG) with 40/70 trees/ha.

2.3.3 Economic assessment

The interviewed farmers developed two main strategies to improve the profitability of their agroforestry practices: innovative marketing of tree products and/or profiting from maximum payments for ecosystem services. Under the baseline condition (BASIC_A), 8 out of 14 of the agroforestry practices were economically competitive after 60 years, compared to the respective monoculture (Table 4). Under the pessimistic assumption (BASIC_P), the reduction of the tree product price by 10% had a significant impact on the profitability, particularly for the fruit producing systems. A premium product price increase by 10% (BASIC_O) turned 10 agroforestry practices more competitive. The ecological innovation scenario (ECO) was the only strategy where 100% of the agroforestry practices were more profitable than the monoculture.

Table 2.4: Net present value (SFR/ha^{-1}, 3.5% discount rate) 10, 30 and 60 years after tree planting for the 4 scenarios: a) baseline (BASIC_A); b) pessimist (BASIC_P); c) optimist (BASIC_O) and c) ecological innovation (ECO). For the tree-crop combinations timber-arable (TA), fruit-arable (FA), timber-grassland (TG) and fruit-grassland (FG) with 40/70 trees/ha. The references are the arable (rotation: oilseed/w-wheat/rotational grassland/w-wheat) and grassland monocultures.

Agroforestry practices	**a) BASIC_A**			**b) BASIC_P**			**c) BASIC_O**			**d) ECO**		
Timber (T)/ Fruits (F)	SFR/ha in year			SFR/ha in year			SFR/ha in year			SFR/ha in year		
Arable (A)/ Grassland (G)	10	30	60	10	30	60	10	30	60	10	30	60
Arable monoculture	13'533	29'510	41'008	13'533	29'510	41'008	13'533	29'510	41'008	13'533	29'510	41'008
Wild cherry (TA40)	10'182	24'579	35'763	10'182	24'579	35'212	10'182	24'579	36'315	**14'128**	**33'827**	**47'258**
Wild cherry (TA70)	11'001	27'328	40'019	11'001	27'328	39'207	11'001	27'328	40'831	**13'805**	**35'261**	**51'411**
Walnut (TA40)	11'352	21'298	38'751	11'352	21'298	37'863	11'352	21'298	39'638	**15'581**	**30'467**	**48'465**
Walnut (TA70)	13'113	23'487	**46'920**	13'112	23'487	**45'683**	13'112	23'487	**48'156**	**15'183**	**32'091**	**60'020**
Walnut (FA40)	-1'661	23'442	38'049	-2'214	17'820	28'990	-1'246	27'658	**44'844**	5'027	**32'491**	**48'265**
Walnut (FA70)	-7'089	27'909	**48'280**	-7'969	18'965	33'867	-6'429	**34'616**	**59'089**	1'136	**38'847**	**61'360**
Grassland monoculture	10'542	23'554	32'469	10'542	23'554	32'469	10'542	23'554	32'469	10'542	23'554	32'469
Wild cherry (TG40)	7'903	23'106	**36'629**	7'903	23'106	**35'212**	7'903	23'106	**37'196**	**12'095**	**32'333**	**47'285**
Wild cherry (TG70)	8'642	**26'618**	**43'435**	8'642	**26'618**	**42'599**	8'642	**26'618**	**44'271**	9'815	**30'251**	**50'095**
Walnut (TG40)	8'051	11'561	26'264	8'051	11'561	25'376	8'051	11'561	27'152	**12'574**	22'598	**40'513**
Walnut (TG70)	8'978	17'271	**40'525**	8'978	17'271	**39'289**	8'978	17'271	**41'761**	6'679	**25'652**	**51'596**
Wild cherry (FG40)	-5'426	16'893	**33'973**	-5'526	14'602	29'603	-5'338	18'914	**37'829**	1'880	**27'842**	**45'371**
Wild cherry (FG70)	-12'383	16'678	**40'539**	-12'542	13'033	**33'586**	-12'242	19'894	**46'674**	-4'468	**26'643**	**49'867**
Walnut (FG40)	-4'439	16'322	29'361	-4'992	10'701	20'302	-4'024	20'539	**36'155**	2'361	**26'029**	**41'141**
Walnut (FG70)	-10'826	20'941	**41'158**	-11'706	11'997	26'746	-10'166	**27'648**	**51'968**	-3'698	**31'452**	**53'131**

Most interviewed farmers were interested in fruit production. This finding contrasts with most recent research publications, which focused on high value timber (Van der Werf et al., 2007; Graves, 2007; Dupraz and Liagre, 2008; Reeg, 2009). According to our results, both systems have advantages and disadvantages.

The advantages for the timber system are: lower investment costs and more space below the tree canopies, which is critical today with regard to the large farming machines. In contrast, the fruit option provides regular income, which makes the high density fruit agroforestry practices more profitable. The disadvantage is that mechanization is still underdeveloped for such intercropped orchard systems. Another risk for the fruit system is the low average fruit prices for tree products (Alder, 2007). However, the product innovation strategy shows that farmers can find niche markets such as high quality premium products or local specialties. Herby, walnut production has currently a great potential in Switzerland due to high market prices for the fruits and the high-value timber.

The long establishment phase is a main disadvantage of agroforestry, which makes tree planting expensive and not attractive. This is particularly the case with fruit production, due to higher planting and maintenance costs. Therefore, we recommend introducing establishment payments to create incentives for planting trees.

In most cases the simulated silvoarable options were more profitable than the corresponding silvopastoral options. This is surprising as silvoarable practices are largely abandoned today (see classification results above). Other European studies confirm that silvoarable practices can fit into modern farming schemes in a productive and profitable way (Graves et al., 2007; Dupraz and Liagre, 2008).

Furthermore, the economic scenarios showed the importance of payments for ecosystem services. With 15 SFR/tree^{-1} agroforestry practices are likely to be unprofitable, particularly with low tree product prices (Alder, 2007; Ferjany and Mann, 2007). The recently introduced ecological payment scheme of 45 SFR/tree^{-1} is needed to support farmers to cover the tree maintenance costs.

Still, how effective can payments for ecosystem services be in the ongoing presence of business as usual direct-payments? For decades the direct-payment systems of many European countries, including Switzerland, have been supporting monocultures which resulted in the abandonment of multifunctional agroforestry practices (Eichhorn et al., 2006). Still, the balance remains in favour of basic payments for monocropping and livestock production, which makes in Switzerland approximately 80% of total direct-payments (Bosshard et al., 2010).

Do Swiss farmers make use of the increased payments for ecosystem services? In the case of agroforestry, most farmers only receive the minimum 15 SFR/tree^{-1} (Sereke et al., 2012). Modern farmers often argue that they rather prefer to be food producers than to be (ecological) direct-payment receiver. In contrast, until the 1950s trees were popular components of the food production systems.

With respect to the social resistance against payments for ecosystem services, the recovery of marketing opportunities for fruits is perhaps the more sustainable way to encourage farmers to plant trees. On the other hand, we argue that the farmers' knowledge systems and expectations need to be recognised in the agro-environmental development programs. With the objective to motivate and empower farmers to freely decide to comply, because of their own understanding that multifunctional agro-ecosystems can lead to a win-win situation, not only for the environment and society but also for the sustainability of their farming systems (Altieri, 1999).

Risks

In the previous section we have shown the sensitivity of the agroforestry system to changes of the tree component revenues. Next, the sensitivity of crop revenue changes in agroforestry versus monoculture was assessed by means of a simple sensitivity analysis. We analyzed the impact of declining/increasing crop revenues on the NPV by methodically changing crop revenues by adding ±10-50%. The arable monoculture was compared to the walnut timber (TA) and fruit (FA) silvoarable practices for 40 and 70 trees/ha. Figure 4 illustrates the high sensitivity of the crop monoculture to changing crop revenues as compared to the four agroforestry practices. The sensitivity analysis indicates that mixing trees and crops mitigates the financial risks, as the revenue sources are diversified. This is not only valid for crop monocultures but also for other monocultures such as timber or fruit plantations. In Switzerland, however, the increasing free trade policy is expected to significantly decrease the crop production revenues (Mack et al., 2006).

Hence, in addition to being more productive, agroforestry is also less risky compared to monoculture. The risk reduction potentials of agroforestry practices were also pointed out by other authors (Fernandes and Nair, 1986).

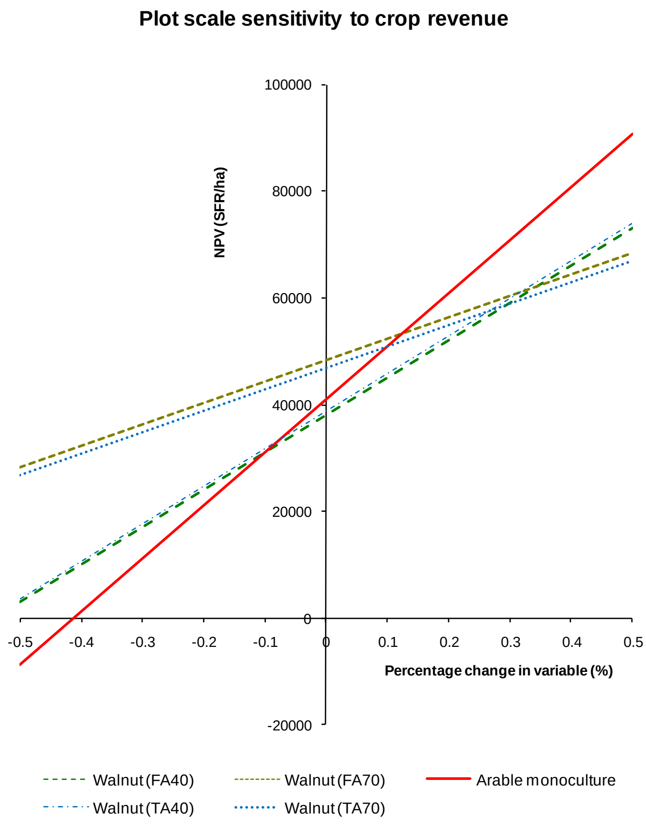

Figure 2.4: Sensitivity to changes in crop revenues: NPV of the arable monoculture compared to 2 walnut and 2 wild cherry silvoarable practices.

2.4 Conclusion

In contrast to the widespread view among modern Swiss farmers that agroforestry is unproductive and unprofitable; we identified living examples of productive and profitable agroforestry practices, developed by innovative farmers. However, we also identified economic uncertainties, which partly explain why agroforestry is not popular anymore. With regard to the long establishment phase, we recommend to introduce establishment payments to motivate tree planting. We also conclude that the increased levels of direct-payments for standard trees are important to support farmers to cover the high maintenance costs, common in Switzerland.

Yet, the unanswered question is why most farmers in Switzerland still resist adopting agroforestry, despite the increased availability of payments for ecosystem services. Competitive direct-payments for business as usual may be one economic explanation. Further transdisciplinary research is needed to fully understand the multiple drivers of farmers' behavior.

This is one of the few studies of modern agroforestry in Switzerland, based on a limited number of agroforestry practices and on model estimations. Hence, field experiments to further validate our model predictions are needed. Furthermore, after decades of neglect, there is need for a wide range of research and development to support the transdisciplinary development of profitable and multifunctional agroforestry systems.

Acknowledgements

Many thanks to the farmers, for their valuable time to explain their real world innovations. Many thanks also to the local research stations for providing data support. The financial support by the MAVA foundation is gratefully acknowledged.

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3 Motivations of Swiss farmers to plant trees - it's not all about money

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Abstract

Agricultural policy in Europe is moving, from decades of supporting large scale monocultures, back towards greater support of multifunctional agriculture. However, modern farmers now appear to be resisting this change in policy focus. For example trees in agricultural landscapes are still declining, despite increasing direct-payments for their maintenance.

The aim of this research is to understand the drivers of farmer behaviour in Switzerland, with regard to agroforestry practices. To this end, a seven-variables-survey was developed building on the concept of ecosystem services and the Theory of Planned Behaviour. The survey consisted of a sample of 50 farmers who were interviewed using a semi-quantitative and open ended questionnaire schedule.

In terms of potential motivations for adoption, most farmers (adopters and non-adopters) gave highest scores to provision of habitat, both for livestock and wildlife. On the other hand, low scores were given to productivity, profitability and ecological direct payments. Notably, farmers resisting adoption concluded that practising agroforestry would not have a positive impact on their reputation. They also attributed significantly lower scores to the perceived behavioral control variable. These results indicate that payments for ecosystem services will be unlikely to change farmers' behaviour, whilst their expectations and knowhow are not holistically addressed. There is therefore a need for transdisciplinary co-production of agroecological knowledge, to cater for the increasing need for multifunctional agricultural landscapes.

Keywords: agroecosystem management, farmer behavior, ecosystem services

3.1 Introduction

3.1.1 Changing policies and landscapes

Until recently multifunctional agroforestry systems, some of them ancient, were a common feature in landscapes throughout much of the world (Nair, 1993; Eichhorn et al., 2006; Gibbons, 2008). These systems were managed to mimic natural ecosystems (Lefroy, 1999). In temperate regions fruit and timber trees as well as hedgerows were combined with arable intercrops (silvoarable systems) or with pastures (silvopastoral systems) in an ecologically complex arrangement. The integrated management of tree, crop and animal biodiversity contributed to the creation of diverse landscapes and synergistic advantages. Agroforestry can combine high levels of productivity for food security with environmental services (Palma et al., 2007b). This can include ecosystem services, such as habitat services (Burgess, 1999; McAdam et al., 2007; Reeg et al., 2009; Kaeser, 2010), climate regulation through CO2 sequestration (Montagnini and Nair, 2004; Palma, et al., 2007a; Briner et al., 2011) and soil and groundwater protection (Lehmann et al., 1999; Palma, et al., 2007a). Trees in agricultural landscapes also provide highly attractive cultural landscapes (Schüpbach, 2009).

However, agricultural policy and research in Europe considerably changed in the second half of the 20th century, encouraging large scale monocultures (Eichhorn et al., 2006). Subsidies were paid to farmers to support a shift towards ecologically simplified agroecosystems. Hence, hedgerows and trees were removed to make way for larger farm machinery. In Switzerland, agroforestry was also popular and widespread until the 1950s (Ewald and Klaus, 2010). But policy interventions in the following decades lead to an 80% decline of the approximately 14 million trees in 1951 to less than 3 million trees in 2001, and their numbers are still declining (BLW, 2005).

Agricultural policy has gradually been refocusing again, as the problematic environmental impacts of large scale monocultures become more clearly understood. In Switzerland a national vote in 1996 revealed, that the vast majority of the public (78%) clearly welcomed a change towards multifunctional agricultural landscapes.

One way to restore multifunctional agricultural landscapes is through revitalizing biodiverse farming systems such as agroforestry. European policymakers are therefore increasingly supportive of the restoration of agroforestry practices through CAP funding, but so far, this appears not to have halted their decline throughout Europe (Smith, 2010).

3.1.2 Changing behavior

This raises the question of how farmers might be motivated to restore agroforestry systems, an approach to farming that has been largely abandoned by research and development in the previous decades. To motivate farmers to manage more complex agroecosystems that are fundamentally different to their current simplified systems is challenging (Pannell, 1999). Once trees have been eliminated from the landscape they require time to be restored, bio-physically, economically and socio-culturally.

While much research has been undertaken to generate knowledge on the bio-economic challenges of agroforestry practices in Europe (Graves et al., 2007), relatively little is known about the socio-cultural driving forces behind farmer behaviour. Most research has been conducted in tropical regions where agroforestry is more widespread (Franzel, 1999; Mahapatra and Mitchel, 2000). Pannell (1999) has reviewed the issue on a global scale and Graves et al. (2009) provided an assessment of farmer attitudes to agroforestry on a European scale, but with little assessment of socio-cultural drivers. The literature suggests that farmers often tend to be risk averse and are reluctant to change their systems unless they are sure of the economic and social consequences (Pluske and Fraser, 1996). Hence, a first precondition to understanding farmer behaviour is a complete picture of the farmers' resources and expectations.

With regard to natural resources, the ecosystem services concept as an integrating framework in ecosystem management has become more widely used (Constanza et al., 1997; Daily, 1997). However, the challenge is still in the implementation of this concept (Ghazoul, 2007; Termorshuizen and Opdam, 2009; Staub et al., 2011). An understanding of how farmers perceive ecosystem services is one important step in promoting the rehabilitation of multifunctional landscapes.

In Switzerland payments to motivate farmers to save farmland trees have tripled since the 1990s, but without success to halt their decline. The main objective of this research is, therefore, to determine potential variables which may explain farmers' behaviour with regard to maintaining tree-rich agroecosystems.

3.2 Method

The study was conducted during 2009-2010 by a multidisciplinary team of scientists. The methodological objective was an integrated assessment of farmer behavior. The following research steps were conducted:

1. Expert and stakeholder workshops
2. Exploratory surveys
3. Main seven variables survey

In an exploratory phase preceding the main survey, expert and stakeholder workshops were conducted to gain an overview of local knowledge and expectations regarding agroforestry in Switzerland. The workshops were also used to identify and recruit innovative farmers, who still practiced agroforestry, for the exploratory survey. A total of 21 preliminary interviews in various parts of Switzerland were conducted, yielding an inventory of a wide range of agroforestry features and functions (Sereke et al., 2012). This information, together with the findings from the workshops, was used to design the main survey.

Finally, the seven-variables-survey was designed using 4 psychological variables from the Theory of Planned Behaviour (Ajzen, 1985, 1991, 2010). The Theory of Planned Behaviour was developed based on the findings of the Theory of Reasoned Action (Fishbein, 1967). The psychological model is an effective guide to preparing a questionnaire to investigate and measure behaviour change. The theory suggests that a person's behaviour depends on the: (i) intention towards the behaviour; (ii) attitude; (iii) subjective norms (the attitudes of important others) and (iv) perceived behavioural control of the behaviour (control and confidence to do it). We assessed these explanatory variables with 1, 14, 7, and 3 items respectively. The expected results indicate which conditions or institutions need to be improved to increase the chance of adoption of the desired behaviour.

Further 3 variables were introduced to apply the Theory of Planned Behaviour for ecosystem management issues. A socio-economic variable was defined, including 17 items to characterise the individual farmer and farming system. Secondly, the ecological motivations for adoption were categorized into 7 ecosystem services as reported for agroforestry by McAdam et al. (2009): production, habitat (shelter, biodiversity), regulation (soil, water, and climate) and culture. Third, economic motivations were assessed through 2 items including profitability of tree products and payments for ecosystem services. Figure 1 presents the seven proposed variables potentially influencing agroecosystem management.

The interview comprised two parts, first the main closed format questions for quantitative analysis, followed by open format questions to record individual opinions. For most variables the response options were based on a 6-point Likert-type item (1 = strongly disagree; 2 = disagree; 3 = slightly disagree; 4 = slightly agree; 5 = agree; 6 = strongly agree). Scores below 4 were indications of obstacles for adoption. Multiple choice questions were used only in variable 1 (Socio-economic characteristics), for the scoring range 0-1 (yes/no) or 1-4 (e.g. total cultivated land: <5, 5-10, 10-20, >20 ha).

Images were used to discuss the different agroforestry practices. The questionnaire was translated into French and German, in order to meet the language preferences of the surveyed farmers. The survey focused on the lowlands (Swiss Plateau) which is the main agricultural production region of Switzerland. Villages were randomly sampled, followed by the random identification of farmers from local telephone directories. Individual face to face interviews were undertaken on the farm, and lasted approximately 60 minutes. The comparison of sample means was achieved using a two-tailed T test. Statistics were computed using Excel 2007 for Windows and the statistic program R.

Lastly, the results of the survey were presented and discussed in various workshops. Additionally, a first multi-stakeholder agroforestry platform was established for Switzerland. This agroforestry association is still active and includes various stakeholders such as farmers, policy makers, scientists, extension experts and environmentalists.

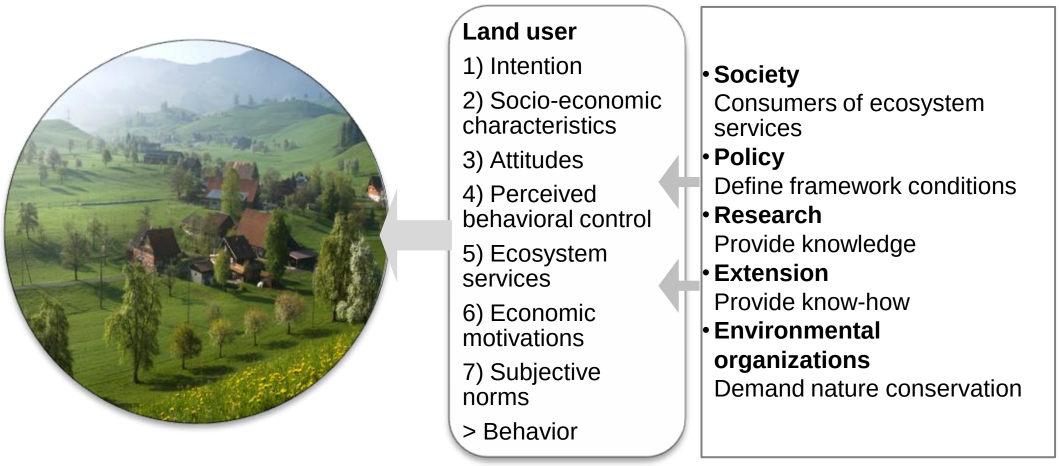

Figure 3.1: The shape of agricultural landscapes depends on the decisions made by the local land users, who act under particular framework conditions. Seven explanatory variables are presented to investigate and measure behaviour change.

3.3 Results

Monoculture crop production was commonly practiced on the flat fields and remnants of former agroforestry practices as well as forests were usually left on the marginal slopes of the farm. Many farmers criticized the frequent changes in agricultural policies over the last decades. In the second half of the 20th century, Swiss authorities run a program for uprooting standard fruit trees to make way for large scale monocultures. In 1975 after increasing complaints by the Swiss public and the juice manufactures the felling actions had to be stopped. Today, public grants are paid to plant trees.

3.3.1 Intention: adopters and non-adopters

52% of the 50 interviewed farmers expressed their intention to maintain or adopt agroforestry. The intentions of the adopters and the non-adopters are shown in Table 1 by the mean intention score of 4.9 by adopters which differed significantly from that of 2.0 by non-adopters ($p<.001$).

In the following assessment the 26 farmers who intend to maintain or adopt agroforestry practices and those 24 who are against adoption were studied separately, to identify differences which rather motivate or discourage adoption. Qualitative statements made by the farmers are presented, in addition to the quantitative results, to provide further explanation of observed views.

3.3.2 Socio-economic characteristics: business as usual

In line with the average of 16 ha farming area per farm in Switzerland (BLW, 2010) the interviewed farmers cultivated on average 10-20 ha. As shown in Table 1 there were no significant differences for farming area between the adopters (score 3.5) and non-adopters (score 3.7). However, the average total number of trees on the adopters' farms (score 2.4) was significantly higher ($p<.001$) compared to non-adopters (score 1.6). All non-adopters practiced conventional agriculture, whereas 12% of the adopters were organic farmers.

Farmers were asked about the economic importance of their farming activities. Nearly all interviewed farms were specialized in common monoculture arable farming or fodder production as well as in animal husbandry. This is in line with our findings in the qualitative study, where one of the farmers said for example: "In the past we learned the importance of diversification, today the demand is specialization" (F8, Arboldswil). Fodder production and livestock were significantly more important on the adopters' farms with $p<.05$ and $p<.001$ respectively.

Trees (forestry or fruit production) played a minor role in the farm businesses, notably, in the adopters and non adopters farms. All adopters and nearly all non-adopters (96%) practiced agroforestry in the past, whereas all adopters still maintain remnants compared to 88% of non-adopters.

No significant differences in the socio-economic variables were found. In terms of sex, 96% of all farms were represented by the male farmers. Notably, only 31% of the adopters and 21% of non-adopters knew about the maximum tree grants available for their region.

Table 3.1: Intention and socio-economic characteristics of the interviewed farmers and their farming system. Mean scores and standard deviations across samples: Farmers all (n=50), adopters (n=26), non-adopters (n=24). Mean comparison is displayed with statistical significance (2 sample T-test). The scoring range for 6-point items is from 1 (I totally disagree/very low) to 6 (I totally agree/very high) and for 4-point items (1 = very low/ 4 = very high). In terms of multiple choice items, the range was 0-1 (yes/no) or 1-4 ([1] <5, 5-10, 11-20; >20 ha; [2] <25, 25-50, 51-75, >75 trees; [3] <20, 20-40, 41-60, >60 years; [4] no formal education, agricultural school, advanced agricultural school, university; [5] <25, 25-50, 51-75, 76-100%).

Variable	Score	Adopters		Non-adopters		All Farmers	
Intention & socio-economics		M	SD	M	SD	M	SD
1) Intention	1_6	4.9	0.7	2.0***	0.7	3.5	1.6
2) Scio-economic characteristics							
Total cultivated land[1]	1_4	3.5	0.7	3.7	0.5	3.6	0.6
Total trees on farm[2]	1_4	2.4	1.1	1.6**	0.9	2.0	1.1
Organic_conventional	0_1	0.88	0.3	1.0	0.0	0.94	0.2
Economic importance:							
Arable cropping	1_4	3.3	0.9	3.2	1.1	3.2	1.0
Fodder production	1_4	3.7	0.7	2.9*	1.4	3.3	1.0
Livestock	1_4	3.8	0.6	2.8**	1.5	3.3	1.0
Forestry	1_4	1.6	1.1	1.3	0.6	1.4	0.9
Fruit production	1_4	1.4	0.9	1.3	0.9	1.4	0.9
History:							
AF practiced in the past	0_1	1.0	0.0	0.96	0.2	0.98	0.1
AF remnants today	0_1	1.0	0.0	0.88	0.3	0.94	0.2
Sex (female_male)	0_1	0.96	0.2	0.96	0.2	0.96	0.2
Age[3]	1_4	3.0	0.7	3.3	0.7	3.1	0.7
Education level[4]	1_4	2.1	0.6	2.3	0.8	2.2	0.7
Availability of successor	0_1	0.38	0.5	0.42	0.5	0.40	0.5
Land leased, not owned[5]	1_4	2.0	1.0	2.0	1.1	2.0	1.0
Know-how: practicing AF	1_6	4.0	1.0	3.6	1.1	3.7	1.1
Know-how: tree grants	0_1	0.31	0.5	0.21	0.4	0.26	0.4

* p < .05, ** p < .01, *** p < .001

3.3.3 Pessimistic attitudes and popular fruit orchards

Regarding the farmers` attitudes we found that, farmers would plant trees for fruit production rather than high value timber or biomass (for energy) production (Table 2). Non-adopters are generally less interested in tree products (p<.05).

Orchard silvopastoralism is still the most popular agroforestry system. The farmers' second choice is forest grazing. Farmers often mentioned that they would like the forest grazing system, but today it's not allowed anymore. Still, some farmers allow their livestock to enter the forest, illegally. Even windbreaks/hedgerows and boundary planting which would occupy little crop space on the field edges are not popular.

Remarkably, adopters and non-adopters were convinced that agroforestry is not productive compared to monoculture. Non- adopters had a significantly more negative attitude regarding productivity ($p<.001$).

Most farmers agree that the performance and management (e.g. mechanization) are disadvantages of agroforestry practices. Availability of tree grants and extension also received low scores (<4).

Table 3.2: Attitudes towards practicing agroforestry. Farmers were asked whether the following variables represent opportunities/strengths or weaknesses of agroforestry practices. Mean scores and standard deviations across samples: Farmers all (n=50), adopters (n=26) and non-adopters (n=24). Mean comparison is displayed with statistical significance (2 sample T-test). The scoring range is from 1 (I totally disagree/very low) to 6 (I totally agree/very high).

Variable		Adopters		Non- adopters		All Farmers	
3) Attitudes		M	SD	M	SD	M	SD
Agroforestry products and practices							
Tree products	Biomass	2.1	1.4	2.3	1.4	2.2	1.4
	Timber	2.7	1.5	1.8*	1.0	2.3	1.3
	Fruits	4.1	1.1	3.4*	1.5	3.8	1.3
Agroforestry practices	Silvoarable	2.3	1.3	1.9	1.2	2.1	1.2
	Windbreak	3.9	1.7	3.0	1.7	3.5	1.7
	Boundary planting	3.9	1.6	3.3	1.5	3.6	1.6
	Forest grazing	4.0	1.9	3.4	1.9	3.7	1.9
	Silvopastoral	4.9	1.0	3.7**	1.7	4.3	1.5
Productivity and management							
Productivity		3.0	0.7	2.0***	0.7	2.5	1.0
Riskiness		3.2	0.9	2.7	1.1	3.0	1.4
Intercrop competition		3.1	0.8	2.8	1.3	2.9	1.4
Mechanization		3.1	0.8	2.6	1.2	2.9	1.5
Framework conditions							
Availability of tree grants		2.5	1.3	2.7	1.7	2.6	1.5
Availability of extension		3.7	1.3	3.4	1.0	3.6	1.2

* $p < .05$, ** $p < .01$, *** $p < .001$

3.3.4 Low perceived behavioral control

The perceived behavioral control (of practicing agroforestry) variables revealed that all interviewed farmers feel rather free to decide whether to practise agroforestry or not (Table 3). But they believe that framework conditions rather don't allow adoption (scores <4). Furthermore, both farmer groups are not confident in managing agroforestry practices, while non-adopters feel even significantly less confident (p<.001).

Table 3.3: Perceived behavioral control of practicing agroforestry. The questions in this item refer to whether: farmers feel free to decide for adopting agroforestry; framework conditions allow them to practise agroforestry and they feel confident to manage agroforestry practices. Mean scores and standard deviations across samples: Farmers all (n=50), adopters (n=26) and non-adopters (n=24). Mean comparison is displayed with statistical significance (2 sample T-test). The scoring range is from 1 (I totally disagree/very low) to 6 (I totally agree/very high).

Variable	Adopters		Non- adopters		All Farmers	
4) Perceived behavioral control	M	SD	M	SD	M	SD
Control over decisions	4.5	1.4	3.9	1.4	4.2	1.4
Confidence in framework conditions	3.6	1.3	2.9	1.4	3.3	1.4
Confidence to manage	3.8	1.2	2.4***	1.3	3.2	1.3

* p < .05, ** p < .01, *** p < .001

3.3.5 Ecological motivations

Farmers were asked about potential ecosystem services which would motivate them to practice agroforestry (Table 4). The primary motivations were habitat function, both for biodiversity conservation and shade for livestock. Significantly lower scores (p < .01) by non-adopters compared to adopters were identified regarding their motivation to conserve cultural landscapes through agroforestry. Environmental regulation is not a motivation for both adopters and non-adopters.

3.3.6 Economic de-motivations

None of the farmers viewed economic benefits from marketing tree products as a motivation to practice agroforestry, with non-adopters being more pessimistic (p< .01) (Table 4). Statements on this issue were like: "I used to get good prices for my cherries, but in the last 20-30 years the prices have drastically declined. The fruit prices and qualities are dictated by the two largest retailers" (F6). "There is a lack of markets, the only option is direct marketing" (F5, Halten). Similarly, ecological grants do also not motivate farmers to plant trees (Scores < 4).

Table 3.4: Ecological and economic motivations for adoption. Farmers were asked whether the listed ecosystem services and economic variables represent potential motivations to practice agroforestry. Mean scores and standard deviations across samples: Farmers all (n=50), adopters (n=26) and non-adopters (n=24). Mean comparison is displayed with statistical significance (2 sample T-test). The scoring range is from 1 (I totally disagree/very low) to 6 (I totally agree/very high).

Variable		Adopters		Non- adopters		All Farmers	
Motivations for adoption		M	SD	M	SD	M	SD
5) Ecosystem services							
Production (subsistence)		4.5	1.2	3.9	1.5	4.2	1.4
Regulation	Soil	3.7	1.4	3.4	1.2	3.6	1.3
	Water	3.3	1.3	3.2	1.2	3.3	1.2
	Climate	3.1	1.5	3.0	1.3	3.1	1.4
Habitat	Shelter	5.0	1.0	4.5	1.3	4.8	1.2
	Biodiversity	5.0	0.8	4.5	1.2	4.8	1.0
Cultural landscape		4.7	0.8	3.8**	1.4	4.3	1.2
6) Economic motivations							
Profitability of tree products		3.0	1.2	2.3*	1.3	2.6	1.3
Payments for ecosystem services		3.6	1.4	3.2	1.2	3.4	1.3

* p < .05, ** p < .01, *** p < .001

3.3.7 Subjective norms: reputational risks

In terms of subjective norms about practicing agroforestry, farmers were asked whom they expect to approve the adoption of agroforestry. In most items both farmer groups had similar expectations. They expected that their fellow farmers would not approve agroforestry practices, in contrast to the Swiss public and environmentalists who are expected to highly welcome agroforestry. Non-adopters generally expected lower approval levels.

Finally, farmers were asked whether adoption would have a positive effect on their reputation. Remarkably, only adopters concluded that adopting agroforestry would have a positive impact on their reputation, in contrast to the non-adopters (p<.01).

Table 3.5: Subjective norms about practicing agroforestry. Two questions were asked: (i) Which stakeholder do you expect to approve the adoption of agroforestry? (ii) Would adoption have a positive effect on your reputation? Mean scores and standard deviations across samples: Farmers all (n=50), adopters (n=26) and non-adopters (n=24). Mean comparison is displayed with statistical significance (2 sample T-test). The scoring range is from 1 (I totally disagree/very low) to 6 (I totally agree/very high).

Variable	Adopters		Non- adopters		All Farmers	
7) Subjective norms	M	SD	M	SD	M	SD
Agroforestry would be approved by:						
Fellow farmers	3.0	1.0	2.3*	0.9	2.7	1.0
Extension officers	3.8	0.8	3.1*	1.0	3.5	1.0
Scientists	4.2	1.0	3.5*	1.0	3.9	1.1
Agricultural policymakers	4.7	1.0	4.3	1.1	4.5	1.1
Swiss public	4.9	0.8	4.9	0.7	4.9	0.8
Environmentalists	5.6	0.7	5.6	0.8	5.6	0.8
Effect on reputation	4.4	1.1	3.5**	1.2	3.9	1.2

* p < .05, ** p < .01, *** p < .001

3.4 Discussion

The seven variables survey was a valuable framework to assess Swiss farmers' perception of agroforestry. In the following section, we will discuss the survey results to further explore potential opportunities and barriers with regard to adopting agroforestry.

3.4.1 Intention: two knowledge systems

Two farmer groups were identified, indicated by the significant differences in the intention levels to maintain or adopt agroforestry practices (Table 1). In addition to the quantitative differences, the following qualitative statements underline the differences of the two perceptions. We spoke to monoculture oriented farmers, resisting the re-integration of trees: "My first thought was: are they crazy? How can this be compatible with today's mechanization" (F13, Dachsen). "If it is dry, trees are a competition to the intercrop" (F5, Halten).

In contrast, more ecologically oriented farmers welcomed the actual ecologisation efforts and were ready to maintain or adopt agroforestry practices, such as this farmer: "Yes agroforestry is an interesting option. The youth need opportunities for the future" (F7, Liestal, BL). "Yes, agroforestry is productive: there is a balance between loss through shade and benefits thanks to the fruit yields" (F3, Niederwill).

This and the following results indicate that the two farmer groups are linked to specific knowledge systems, which can be defined as agro-industrial or agroecological knowledge systems (Roling and Engel, 1991; Altieri and Toledo, 2011). A knowledge system is a specific mental construct within specific actor networks. In terms of agriculture such networks include consumers, farmers, extensionists, scientists, policymakers and, in the case of the agro-industrial approach, powerful agro-companies (Roling, 1996).

3.4.2 Opportunity costs: barrier for change?

Most interviewed farmers were specialised in crop or livestock production, whereas trees were of minor importance in their farming system (Table 1). Similarly, farmers were only interested in silvopastoral practices but not in systems where trees or hedges interfere with arable fields (Table 2).

"If ecosystem services are to form a successful basis for land management and conservation, then one needs to be realistic about the opportunity costs as viewed from land managers' perspectives" (Ghazoul, 2008). For decades the grant systems of many European countries, including Switzerland, were supporting high input monoculture which resulted in the abandonment of multifunctional agroforestry practices by farmers to maximise subsidy income (Eichhorn et al., 2006). In the 1990s the Swiss policy has officially declared the move towards a balance between food production and conservation. Yet, the balance is still in favour of business as usual, which is supported by approximately 79% of the total public grants and a fraction of the remaining 21% supports multifunctional practices such as agroforestry (Bosshart et al., 2010). This might be a monetary explanation that the surveyed farmers are still comfortably specialized in monoculture crop production and livestock (Table 1). However, the actual development of the grant system is promising, increasing payments for ecosystem services can render agroforestry economically competitive (Sereke et al., 2012). Hence the opportunity costs are gradually declining - at least the monetary.

3.4.3 Farmer-led joint research

Considerable differences in the attitudes of farmers and recent agroforestry research were found. Science has found for temperate regions of Europe, that the integration of high value timber (Graves et al., 2007) or biomass producing trees (Wagner et al., 2009) into arable fields is a promising multifunctional business. Most interviewed farmers, however, were less interested in high-value timber or biomass production as well as re-integrating trees into arable fields, but in fruits combined with grassland. Furthermore, farmers see agroforestry as less productive than monoculture, in contrast to actual scientific evidence in Switzerland (Sereke et al., 2012) and other temperate regions of Europe (Graves et al., 2007). Today, monoculture oriented farmers seem to perceive biodiversity in the form of trees or hedges as obstacles to meet the main crop production target. In spite of increasing evidence which show that biodiversity and biological regulation functions are important for the stability of crop production systems (Altieri, 1999).

These examples indicate that there is a lack of communication between science and real world practice, i.e. lack of transdisciplinary collaboration. Farmer-led joint research can support collaborative development of locally adapted technologies (Wettasinha and Waters-Bayer, 2010). Observable field trials or farmer field schools can address uncertainties in managing modern agroforestry practices.

3.4.4 Towards ecological and economic win-win solutions

Promoting and facilitating well-liked ecosystem services can increase the overall popularity of agroforestry practices. In terms of potential motivations to adopt agroforestry, the primary motivations of adopters and non-adopters were the habitat functions, both for biodiversity conservation and shade for livestock.

The most significant difference with regard to ecosystem services was that non-adopters did not consider restoring cultural landscape as motivation for adoption. Hence, the two knowledge systems seem to have different perceptions of (agri) cultural landscapes. This may be one reason why non-adopters did not perceive agroforestry as good for their reputation.

In terms of economic benefits most farmers did not view economic benefits as motivation. The low score for the profitability of (high-stem) tree products can be explained by today's commonly low fruit prices combined with high production costs in Switzerland (Alder, 2007). Still, agroforestry practices can be economically competitive compared to arable and grassland monocultures, through innovative marketing of the fruits or payments for ecosystem services or (Sereke et al., 2012). Commonly, farmers benefit from only 15 SFR/tree^{-1} as basic production grants; whereas a total of 50 SFR/tree^{-1} would be available when farmers participate in ecological grant scheme. However, the majority of the interviewed farmers did not know about the potential payments for trees available in their region (Table 1). More remarkably, farmers did not view payments for ecosystem services as a motivation for adoption (Table 3). Hence, Swiss farmers accept grants for production, which make up a considerable part of their revenues, but resist grants for other ecosystems services.

But again there are two different views on this issue depending on the knowledge system. The following remark underlines the conventional knowledge system: “It’s unfair, those who do something and those who do nothing get the same grants” (F3, Niderwill). The results indicate that the (conventional) farmer group perceive ecosystem services as “doing nothing”, and with regard to the subjective norm variable (Table 5), bad for their reputation. In contrast this more ecologically oriented farmer said, reflecting on the consequences of the Swiss grant system: “The only subsidies which make sense in developing agriculture are payments for ecosystem services”.

The social resistance by the conventional farmers can be partly explained by the traditional understanding that farmers produce food. However, when agroforestry practices were popular (before the 1950s), fruits from local standard trees were an essential part of the human diet and farm income.

Our findings indicate that restoring the market for fruits (from standard trees) would rather motivate farmers than increasing direct-payments. In this way producing healthy food would lead to healthy landscapes, a characteristic example of realizing win-win solutions.

Still, a broader knowledge about ecosystem services needs to be made available to farmers and to the society at large, to increase recognition of local ecological solutions.

Systematic valuation and official recognition of ecosystem services would support such development. However, the implementation of the concept of ecosystem services is still underdeveloped, internationally (Ghazoul, 2007) as well as in Switzerland (Staub et al., 2011). Despite the increasing availability of frameworks and methods for implementation (Termorshuizen and Opdam, 2009).

3.4.5 Exchange to overcome social resistance

Non-adopters, in contrast to adopters concluded that adoption would not have a positive effect on their reputation. These results indicate that reputation is a critical explanatory variable in farmers' non-adoption. Comparing both knowledge systems, non-adopters' behavior seems to be more oriented towards the opinion of their colleagues than towards the opinion of society and environmentalists. A lack of sympathy against environmentalists was often mentioned by non-adopters for example: "I fear environmentalists like a sword" (F13, Dachsen). Increasing environmental restrictions are obviously not welcomed by conventional farmers.

Exchange, trough for example multi-stakeholder platforms (Critchley et al., 2006; Burkhardt-Holm, 2008), could reduce the gap between different interest groups and facilitate collaborative landscape improvements. The reputation of ecological innovations can further be improved through a fair coverage of the wide range of ecosystem services provided by agroecosystems, in the farmers' education and relevant media. As (Swiss) farmers are commonly traditionally oriented, the promotion of the cultural benefits of tree-rich cultural landscapes is also important.

An example of how transdisciplinary collaboration can lead to sustainable farming systems was demonstrated by the significant rise of organic farming in Europe (Aeberhard and Rist, 2009). The increase of the consumers valuation of organic products further motivated farmers to shift from the (still dominant) conventional to the organic agriculture. However, the further transition from industrial towards agroecological farming systems requires a fundamental shift towards transdisciplinary collaboration. The aim is the 'application of ecological science to the study, design and management of sustainable agroecosystems' (Altieri 2002). The aim is the design of biodiverse landscape mosaics with various tree and crop species and varieties, to promote diet diversity and ecological economic resilience.

Facilitation of legal conditions is also crucial as the current segregation of forestry and agriculture is an obstacle in restoring multifunctional landscapes (Rigueiro-Rodríguez et al., 2009). Herby, one of the first actions of the recently established Swiss multistakeholder platform (by the authors) was to compile a list of demands for the local authorities to facilitate the ongoing agroforestry restoration efforts.

3.5 Conclusion

The seven variables survey identified various social, economic and technical barriers to adopt agroforestry practices, from the farmers' perspective. The results indicate that payments for ecosystem services have not been successful to change farmers' behaviour due to non-monetary obstacles, such as reputational risks.

Hence, a fundamental shift of research and development towards multifunctional agroecosystems is required today, to empower farmers to change. As "you cannot solve a problem from the same consciousness that created it. You must learn to see the world anew" (Albert Einstein).

One step has been taken by this project with the founding of a multistakeholder platform, to facilitate transdisciplinary collaboration in developing Swiss agroforestry. And a more critical step by the Swiss agro-environmental policy, by gradually updating the direct-payment system. This is encouraging for farmers to develop productive and multifunctional agricultural landscapes.

Acknowledgements

We like to thank the farmers for spending their valuable time in explaining us the benefits and risks of farm trees. The financial support by the MAVA foundation is gratefully acknowledged.

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4 Developing tree-rich agroecosystems – lessons from transdisciplinary success stories

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Abstract

The expansion of simplified agroecosystems led to the widespread degradation of tree-rich cultural landscapes, both in tropical and temperate ecoregions. Today, efforts are made to restore multifunctional agroforestry practices and their ecosystem services.

This paper presents case studies were successful transdisciplinary collaboration led to the development and expansion of agroforestry practices. One is the “Streuobst” success story, also known as “central European savannas”, between the 1850s and the 1950s. The second is the Sahelian “alternative green revolution” in the savannah parklands of West Africa, which is ongoing.

Both cases demonstrate how large-scale landscape improvement and positive change can be achieved, through a bundle of interconnected scientific, technical and institutional innovations. We need to: (i) co-produce visions, knowledge and technologies in realizing synergies among limited landscape resources; (ii) create market opportunities for ecosystem goods and services and (iii) empower sustainable policies and community based governance of multifunctional landscapes.

Keywords: transdisciplinary collaboration, agroecosystem rehabilitation, agroforestry

4.1 Introduction

Agroforestry is an ancient land-use system that shaped multifunctional landscapes throughout the world (Nair, 1993; Bürgi and Stuber, 2003; Fukamachi et al., 2003). The integrated management of tree, crop and animal biodiversity contributed to the creation of diverse and productive landscapes. These landscapes played an important role in providing food, firewood, timber and medicinal plants for rural livelihoods as well as shelter and forage for livestock. Further ecosystem functions provided by agroforestry include habitat (Burgess, 1999; McAdam, 2007; Reeg et al., 2009; Kaeser et al., 2010), climate regulation through CO2 sequestration (Montagnini & Nair, 2004; Palma, et al., 2007; Briner et al., 2011) and soil and groundwater protection (Lehmann et al., 1999; Palma et al., 2007). Tree-rich agricultural landscapes play also an important social-cultural role for the society (McAdam, 2009).

However, the expansion of simplified agroecosystems, especially in the 20th century, led to the widespread degradation of tree-rich agricultural landscapes across the globe (Eichhorn et al., 2006; Fukamachi et al., 2003; Rigueiro-Rodriguez et al., 2009). Today, efforts are made by science and policy to restore multifunctional agroforestry practices and their ecosystem services (Dupraz et al., 2005; Graves et al., 2007; Sereke et al., 2012b).

Transdisciplinary collaboration is vital to facilitate the ongoing efforts to restore agroecosystems in both low- and high-income-countries. For example in Switzerland, transdisciplinary co-production of knowledge facilitated the development and expansion of sustainable organic agriculture (Aeberhard and Rist, 2009). "The core idea of transdisciplinarity is different academic disciplines working jointly with practitioners to solve a real-world problem" (Klein et al., 2001). A wide range of transdisciplinary approaches are available to facilitate joint conflict solving among a wide range of stakeholders (Hirsch Hadorn, 2008; Pohl et al., 2010). Three modes of integration and forms of collaboration can be defined: common group learning (e.g., Schelling et al., 2008); negotiation among experts (e.g., Ravnborg and Westermann 2002; Oswald and Baccini, 2003) or integration by sub-groups and individuals (e.g., Wuelser et al., 2012).

Dynamic livelihood responses can be observed when today's developments in the South are compared to the history of the North. For example today, goods and services from trees play a vital role for the survival of local populations in southern low-income-countries, as compared to high-income-countries. This was not always the case and may also change in the future, as the responses of people seeking rural livelihoods in both North and South are complex and dynamic (Küchli, 1994).

In this study, the historical development of agroforestry practices in a northern temperate context is assessed in comparison to a more recent agroforestry development under sub-tropical conditions in the South. The objective is to explore the drivers of land use change under contrasting time and space contexts, in order to identify shared lessons towards the successful co-development and expansion of agroforestry practices.

The first case study explores the successful development and expansion of agroforestry in Central Europe, i.e. „central European savannas" (Luick, 2009), with emphasis on Germany around 1850–1950 (Lott, 1993). This is compared with a case study from the West African Sahel (Niger and Burkina Faso), covering the last three decades (Reij et al., 2009). Similar historical developments can be observed in other high- and low-income regions. Parallel to the developments in the Sahel, for example, "alternative green revolutions" towards agroecological transformations are reported from South America (Altieri and Toledo, 2011). With regard to the historical developments in temperate regions, agroforestry practices where widespread and played an important role until the 1950s, such as in central Europe (Oosterbaan and Kuiters, 2009; Eichhorn et al., 2006), Japan (Fukamachi et al., 2003) or the United States (Zinkhan et al., 1997; Garrett et al., 2009). In Europe, renowned Roman authors already recommended the conservation of farm trees, not only to maintain the sustainability of agriculture but also of a "sustainable society" (Lelle and Gold, 1994).

4.2 The "Streuobst" success story (1850–1950)

4.2.1 Historical developments in Central Europe

The challenges of the 19th century in Central Europe were food insecurity and population growth, as well as decreasing landholdings and lack of knowledge in professional fruit production (Lott, 1993). After the era of enlightenment in the 18th century, reformists criticised that the bonded and oppressed farmers could not feed the growing population. Poverty, famines and uprisings led to a change of the ruling elites towards democracy and more rights for the farmers (Schneider, 2007).

Until a century ago, there was no distinct boundary between agriculture and forestry in Europe, as agroforestry practices were widespread (Brownlow, 1992; Stuber and Bürgi, 2001; 2002; Bürgi and Stuber, 2003). With increasing pressure by a fast-growing population, combined with the upcoming of market-oriented timber production and the rise of industry, forest resources were largely degraded by the end of the 19th century. In the meanwhile, farmers intensified tree planting on their agricultural fields and were supported by various research and development projects. Agroforestry research and development (R&D) was interrupted in the second half of the 20th century, as agricultural policy shifted toward favouring mechanized monocultural systems (Herzog and Sereke, 2011). After World War II, agricultural grant systems discouraged the maintenance of farm trees, as these made the farmers ineligible for subsidy payments (Eichhorn et al., 2006). Most of the standard trees and hedgerows in Central European landscapes were removed to allow effective management of larger fields with larger machines. For example in Switzerland 80% of the (high-stem) trees in agricultural landscapes were felled between 1951 and 2001 (BFS, 2001).

By the early 1990s, the unsustainable environmental impacts and overproduction forced policy to move back towards multifunctional agriculture (Oosterbaan and Kuiters, 2009; Graves et al., 2007). Since then, agricultural policies in several Central European countries have started to provide payments for ecosystem services in an effort to halt the ongoing loss of tree-rich multifunctional landscapes. Still, without success to halt their decline (Eichhorn et al., 2006; Smith, 2010). Modern farmers today are commonly not willing to restore multifunctional agroforestry systems, due to a wide range of monetary, technical and social driving forces (Sereke et al., 2012a).

4.2.2 What was achieved?

This case study demonstrates how transdisciplinary collaboration facilitated the development and diffusion of diverse and productive agroforestry systems in Germany between the 1850s and 1950s (Lott, 1993). It focuses on the development of intercropped orchard systems with the local name “Streuobst” (Herzog, 1998), also known as “central European savannas” (Luick, 2009). These traditional orchards are characterised by widely spaced standard fruit trees of diverse varieties. They are either intercropped with fodder grass or grazed (silvopastoral systems), or intercropped with arable crops (silvoarable systems).

As in other European countries (Eichhorn et al., 2006; Rigueiro-Rodriguez et al., 2009), in half a century (since the 1850s) large-scale transformation of agricultural landscapes was achieved, through the integration of standard trees. These systems not only yielded goods for the livelihoods of the local people, but also represented highly biodiverse cultural landscapes, until the 1950s (Herzog, 1998).

4.2.3 How was it achieved?

As the forest resources declined, farmers started to plant fruit trees on their agricultural land for subsistence needs and cash income. However, farmers were not willing to significantly decrease the size of their relatively small crop fields and pastures to adopt monocultural fruit production. Hence, they explored ways to integrate high-stem fruit trees in a multidimensional design, allowing continuous intercropping. Consequently, R&D supported the development of such agroforestry systems with respect to the expectations and innovations by the local farmers. A wide range of stakeholders and institutions such as scientists, policy makers, fruit growers' associations and the private sector supported the development of fruit production. E. Lucas (1818–82), for instance, established in 1860 the first German institute for fruit production in Reutlingen. Remarkably, the need for transdisciplinary research was understood, as the objective was "not to fill up young people with science and theories, but to educate a generation of scientists who can work practically" (translated from Lott, 1993, p. A42, Reference 80). Figure 1 presents one of many agroforestry design options developed by scientists in Germany in the 19th century, where densely planted tree lines were combined with intercropped alleys.

Although most activities were undertaken in collaboration, the actors in the transdisciplinary R&D process can be summarized as follows (Lott, 1993):

- Innovative farmers provided knowledge through active participation in the R&D activities and through farmer-to-farmer extension;
- Various local stakeholders (e.g., teachers or spiritual leaders) promoted the image of fruit production. New technologies were developed by the farmers and the private sector, such as tools for post-harvest fruit processing;
- Agricultural and horticultural societies were instrumental in providing local platforms for exchange and transfer of knowledge. With time, their importance decreased, as centralised governmental institutions took over their role;
- Scientific institutions prepared a "scientifically and practically educated elite", aiming at enhancing the productivity of agroforestry practices through demonstration farms and field experiments;

- Fruit-production experts developed knowledge on promising tree species, breeding and tree management;
- The government improved farmers' land and tree use rights, provided financial support for R&D activities, established federal tree nurseries and helped to develop marketing opportunities.

It is interesting to note that cultural aspects and landscape aesthetics were integral parts of the farming system development. In line with the enlightenment and reformation movements since the 18th century, the motto was balancing beauty and utility.

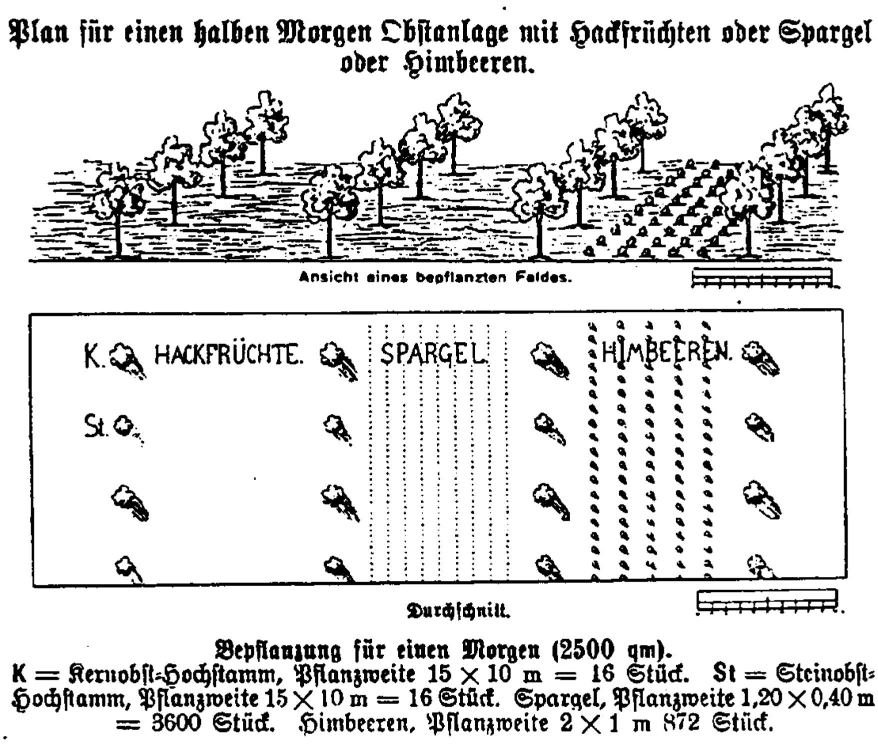

Figure 4.1: "Plan for a fruit orchard of half a morgen [ca. 0.12 ha] with root crops or asparagus or raspberries" established at the turn of the 19th to the 20th century. In the tree lines, pip fruit ("K") and stone fruit ("St") are alternated, tree planting distance is 15 x 10 m (from Lott, 1993, Fig. 12, Reference 229). Similar plans exist for combinations with strawberries, currants, etc.

4.3 The Sahelian “Green Revolution”

4.3.1 Recent developments in the West African Sahel

Similar to the developments in central Europe in the 19th century, many low-income countries have recently experienced a rise in tree planting on farmland in the wake of increasing population pressure and declining availability of forest resources (Arnold and Dewees, 1997; Reij et al., 2009; Bayala et al., 2011; Fifanou et al., 2011).

For example, Niger and Burkina Faso in the West African Sahel experienced “acute human and environmental crisis” in the 1980s (Reij et al., 2009). Deforestation, overgrazing and expansion of monoculture cropping by a fast-growing population led to widespread desertification and famine. Government failure contributed to this crisis: the lack of officially recognised tree and land tenure rights and the promotion of unsustainable monocropping systems discouraged farmers to maintain or adopt agroforestry practices. The post-colonial leaders did not manage to introduce more democratic and sustainable systems for regulating land use, but rather maintained the French colonial approaches.

In the face of this crisis in the 1980s, the local farmers had two options: to rehabilitate degraded land for agriculture or to migrate. The Sahelian “alternative green revolution” since the 1980s resulted from farmers’ decision to stay and rehabilitate degraded land (Reij et al., 2009). However, the battle to restore agroecosystems and food security in the West African Sahel remains a major challenge. Similar to other African regions, there is urgent need to increase food production through the development of biodiverse and productive agroecosystems (UN, 2010).

4.3.2 What has been achieved?

In several African countries, traditional agroforestry systems of savannah parkland, in which farmers selectively leave, protect or plant trees on cropland, have been rehabilitated largely through local initiative (e.g. Bayala et al., 2011, Fifanou et al., 2011, Reij et al., 2009).

Yet, most of the cases are not documented. Therefore, we focus on two cases of successful agroenvironmental transformation in the West African Sahel, documented since the 1980s (Reij et al., 2009). One of these success stories is the rehabilitation of more than 200,000 hectares of degraded land on the Central Plateau of Burkina Faso. The technology “improved traditional planting pits” (“zai”) was developed by local farmers. They improved traditional soil and water conservation strategies to rehabilitate degraded land and to ecologically intensify their farming systems through agroforestry practices.

The second ecological innovation is the natural regeneration of agroecosystems using contour stonebunds and farmer-managed natural rehabilitation (FMNR), using local tree species. Herby, collective action led to the rehabilitation of tree-rich agroecosystems across an area of approximately 5 million hectares in southern Niger.

In both cases, large-scale tree planting restored numerous ecosystem functions, such as environmental regulation (e.g., reduction of wind erosion and CO2 sequestration) as well as production (e.g., soil fertility enhancement through leguminous trees). More resilient farming systems for producing a wide range of products such as cereal crops, fruits, fodder and firewood were developed, both for subsistence and cash income.

The strategies and technologies developed during this innovation process can provide inspiration and knowhow for other African regions, as “the battle against land degradation and poverty has not yet been won” (Reij et al., 2009).

4.3.3 How was it achieved?

Farmer-driven technical innovations led to the landscape transformations in the West African Sahel. The first technology (zai) was the result of farmers’ experimentation (improved traditional planting pits). The other two technologies (contour stonebunds, FMNR) were developed by technical advisors in collaboration with local farmers. The example from Burkina Faso in Figure 2 demonstrates how innovative farmers managed to rehabilitate barren land into productive tree-rich agroecosystems within 20 years (Reij et al., 2009).

This success was the result of the empowerment of local farmers and communities by improved policies such as officially recognised tree and land tenure rights. Combined with transdisciplinary collaboration among a wide range of actors. The development and expansion of the technical innovations across wide distances required enormous collective efforts:

- Innovative farmers trained other farmers. In this process, the farmers did not keep their knowledge to themselves but generously shared their experience;
- Charismatic leaders like prominent farmers or development agents were important in scaling up the agroecological innovations;
- Local governance structures were empowered and traditional work groups revitalized by the local farmer leaders;

- NGOs and other stakeholders facilitated farmer-to-farmer learning and other capacity-building activities;
- National and international scientists collaborated to facilitate exchange of knowledge and to validate and support farmer-led innovations;
- International and national donors supported the land-rehabilitation efforts;
- The government introduced numerous policy reforms, like participation of rural people or making their rights to use land and trees more secure. Marketing opportunities were developed and knowledge co-produced with regard to the public awareness of the environmental crisis and potential agroecological solutions.

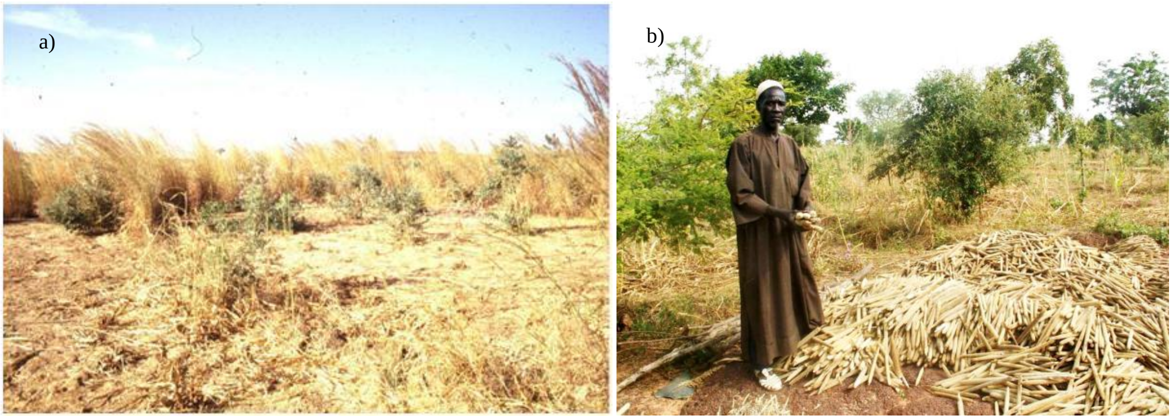

Figure 4.2: The Sahelian "Green Revolution". Example of successful land rehabilitation by an innovative farmer in Burkina Faso (Reij et al., 2009). a) Barren fields without trees in October 1988 and b) the same field in October 2008 with more than 100 baobab trees (*Adansonia digitata*) and other multipurpose tree species (photos: Chris Reij).

4.4 Lessons for fruitful transdisciplinary collaboration

To convince modern farmers to re-adopt traditional combinations of crops with trees is a major task (Graves et al., 2009). Compared to the situation in the south, where small-scale farming is still dominant, most farmers in central Europe are not used anymore to manage trees within and around their fields. Another advantage of tropical agroforestry is that there has been more extensive research and promotion (for example by the activities of the International Centre for Agroforestry Research, www.icraf.org). Whereas it is only recently that temperate agroforestry research has gained some momentum (Herzog and Sereke, 2011).

However, similar to the developments in central Europe, many agroforestry practices in tropical countries are also found in a declining state. Hence, more agroforestry research and development is needed - across the globe. Herby, the high ecological complexity of agroforestry systems (Buttler et al., 2009), requires an integrated management approach. In contrast to such needs, over time, research has become more and more specialised, which lead to a decline in integrated approaches and transdisciplinary collaboration (Constanza et al., 2001; Aeberhard and Rist, 2009). Hence, "the challenge is how best to mobilise specialised talent within a framework that is greater than the sum of the parts" (Cutler et al., 2009). There is need to increase capacity and space for dialogue among disciplines and between science and the real world.

The case studies demonstrate how transdisciplinary collaboration can facilitate the development of sustainable agroecosystems, despite severe levels of degradation and extreme socio-economic and environmental challenges. Effective communication was crucial among a wide range of actors, to address complex and interlinked challenges regarding the natural, social and political capital. Furthermore, awareness among the wider public about the agroenvironmental challenges was enhanced. Both cases managed to create various spaces for collaboration, such as multistakeholder platforms or farmer-to-farmer extension.

The case studies carry the following three important lessons for fruitful transdisciplinary collaboration.

4.4.1 Co-producing visions, knowledge & technologies

Recognition by scientists and extension workers of the innovative energies of farmers in developing their agroforestry practices was a first step toward joint R&D, that is leading to a "regreening" of the Sahel (Sawadogo et al., 2001; Reij et al., 2009). Similarly, the co-production of agroforestry knowledge and technologies in Germany was also supported by a wide range of stakeholders with active participation of innovative farmers (Lott, 1993).

A promising example of how a farmer-driven R&D can be implemented today is demonstrated by the Prolinnova (Promoting Local Innovation) approach (Wettasinha & Waters-Bayer, 2010). Here, transdisciplinary research in close alliance with local farmers is practised, with special regard to local knowledge and endogenous innovation.

In the West-African Sahel farmers developed innovative systems to realize "synergies of soil, water, and vegetative regeneration in a crop, tree and livestock system" (Reij et al., 2009). Yet, research is needed to better understand the complementarities and tradeoffs between components and functions of agroforestry practices. The ecosystem services concept can herby provide a promising conceptual framework (Constanza et al., 1997; Daily, 1997; Termorshuizen and Opdam, 2009). Such integrated approaches in co-producing knowledge require effective ways of exchange, for example through transdisciplinary multistakeholder platforms (Burkhardt-Holm, 2008).

For instance, the authors of this study established a national platform to facilitate transdisciplinary collaboration in developing agroforestry in Switzerland (www.agroforst.ch). Similar efforts in building “knowledge networks” are also made by practioners and scientists in other European countries (Oosterbaan and Kuiters, 2009).

One of the latest large scale agroforestry projects was the SAFE project (Silvoarable Agroforestry for Europe), which produced valuable new data with regard to the design of viable agroforestry options (Dupraz et al., 2005; Graves et al., 2007). Still, there is a lack of knowledge and statistics in the European Union, as well as in Switzerland (Rigueiro-Rodriguez et al., 2009). For example with regard to: accurate land cover by agroforestry systems, the effectiveness of current policy instruments or the interactions between trees and crops. Furthermore, there is a lack of long term field experiments as well as farming tools and technologies to manage modern agroforestry systems.

4.4.2 Creating market opportunities for ecosystem goods and services

Agroforestry practices should provide income for the short- and long-term and be in line with local agri-environment schemes (McAdam and McEvoy, 2009). Marketing of fruits was an important incentive in the expansion of planting fruit trees in Europe in the 19th century. Similar to the Sahelian case, this required investment in the transport system as well as development of marketing opportunities.

Agroforestry can, besides enhancing biodiversity, be productive and profitable as shown by silvopastoral systems in Ireland (McAdam and McEvoy, 2009) or silvoarable systems in several European countries (Dupraz et al. 2005; Graves et al., 2007). Silvopasture can also enhance animal welfare, which is increasingly being demanded by the European Union policy (EU, 2006), as well as in the Swiss direct-payment system (Vogel et al., 2008).

Agroforestry systems can also be of special interest to organic farming, which also aims at managing water and soil resources more efficiently. This can be achieved through complementary in the use of resources by a complex composition of trees and crops (Graves et al., 2007; Van der Werf et al., 2007).

Market opportunities are important triggers for positive change, when they are in line with the overall expectations of the society. The major challenge with trees is time, as it takes more than 1-2 decades to realize the full set of ecosystem goods and services. Therefore, payments for ecosystem services are crucial, especially in the establishment phase of agroforests. The incorporation of the concept of ecosystem services into current landscape improvement efforts is critical, as "much of Nature's labour" is underestimated in the mainstream marketplace (Daily and Ellison, 2002).

Tree-rich agricultural landscapes in Europe are of cultural and historical importance (McAdam, 2009). Hence, one way to market cultural landscapes created by agroforestry practices is through promoting local recreation activities and ecotourism (Pardini 2005; Luick, 2009).

4.4.3 Empowering sustainable policies and local governance

Historically, famine – wherever in the world – may have been the result of droughts or crop failures, but the overall reasons were commonly government neglect and administrative incompetence (Keneally, 2011). The history of both case studies showed that government failures encouraged unsustainable developments, such as the ongoing degradation of tree-rich agricultural landscapes. For example in Switzerland, the post war agricultural policy financed and organised the removal of trees from agricultural land (Herzog, 1998; Ewald and Klaus, 2010).

However, both case studies also demonstrate that constructive governments can lead to positive change, through sustainable policies and the empowerment of local governance. Formal recognition of farmers' rights to use land and trees encouraged farmers in central Europe to invest in sustainable solutions in the 19th century, and encouraged farmers in the Sahel to do the same in the 20th century.

Still, food insecurity is widespread in many African countries and will only become history by further empowering small scale farmers through supportive institutional and legal frameworks. Policymaking and development of new technologies need to consider the complexity and dynamics of local ecosystems and societies (cf. Sendzimir et al., 2011). The importance of traditional agroforestry practices for local food security is reported from numerous African countries (Scoones et al., 2001; Habte and Araya, 2004). Hence, a policy that leads from long-established and resilient farming systems towards a dependency on highly specialized agriculture, can have negative impacts on long established ecological and social balances, both in the southern (Scoones et al., 2001) and the northern context (Ewald and Klaus, 2010).

In the European Union, current developments of the Common Agricultural Policy aim to reduce agricultural externalities of past policies, which motivated farmers to fell farm trees to maximise grant payments (McAdam and McEvoy, 2009). Similarly, there is an ongoing process of agricultural policy reform in Switzerland, seeking a balance between food production and the provision of other ecosystem services from agricultural landscapes (Vogel et al., 2008).

These latest developments are promising, but a fundamental reform of policies has not been achieved. Still, agroforestry “fall between the current European definitions of exclusively forestry and agriculture” (Rigueiro-Rodríguez et al., 2009). This results in an unclear legal status over whether specific agroforestry practices are eligible for Single Farm Payments (Luick, 2009). There is a similar lack of formal recognition of specific agroforestry practices in the Swiss direct payment system.

Hence, there is need for a fundamental reform of policymaking, towards a community based and integrated management of multifunctional landscapes. Clearly, more transdisciplinary research would facilitate evidence based policymaking, through co-producing specific data on the features and functions of agroforestry practices.

Acknowledgements

The financial support by the MAVA Foundation is gratefully acknowledged. We also would like to thank Chris Reij for the inspiring photos from the “alternative green revolution” in the West African Sahel.

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5 Synthesis

5.1 Summary

The aim of this transdisciplinary thesis was to explore bio-economic (theme 1) and socio-economic (theme 2) challenges and opportunities with regard to the agroforestry rehabilitation efforts in Switzerland. And to review transdisciplinary success stories in the development and expansion of tree-rich agricultural landscapes in European and African agro-ecoregions (theme 3).

In theme 1, the exploratory survey yielded a first inventory of features and functions of Swiss farmers' agroforestry innovations. Secondly, the exploratory survey and the bio-economic assessment identified key opportunities and challenges in designing productive and profitable agroforestry practices. A win-win design of locally adapted agroforestry systems is important to optimize productivity, as well as to maximise economic competitiveness. The list of opportunities includes:

- Knowledge on design and functions: The diverse range of identified agroforestry design options are motivating for interested farmers, and the potential ecosystem services can be beneficial for the society;
- Bio-physical opportunities: The bio-physical predictions indicate that 12 out of the 14 assessed agroforestry options are predominantly more productive compared to the monoculture reference;
- Bio-economic opportunities: Modern agroforestry can be economically competitive through either innovative marketing of tree products or through joining profitable ecological payment schemes. Agroforestry reduces the risks of relying on one commodity, through diversification.

However, for a wider uptake various uncertainties and challenges have to be addressed:

- Lack of Knowledge on design and functions: How to enhance extension to promote agroecological knowledge needed to manage modern agroforestry practices? How to incorporate the concept of ecosystem services into mainstream knowledge system?
- Bio-physical challenges: How to co-produce knowledge on tree-crop interactions and the design of productive tree-crop combinations?
- Bio-economic challenges: How can farmers be supported in the long establishment phase before break even? How to increase limited marketing opportunities? Why are farmers despite the availability of ecological payment schemes still resisting the adoption of agroforestry practices?

In the second theme, a seven variables survey to assess Swiss farmers' agroecosystem management was conducted, to shed light on the widespread resistance to adopt agroforestry practices. 50 farmers were randomly selected and interviewed. Almost all farmers were specialized in monocropping and/or livestock production. The remaining farm trees were, according to the farmers, of minor economic interest. The overall results indicate that the increasing role of payments for ecosystem services is important (see also theme 1), but unlikely to change farmers' behavior due to social resistance and lack of knowledge. The results of the seven variables survey indicate the following opportunities:

- Intention: despite the awareness of numerous uncertainties, 52% of the farmers intended to maintain or adopt agroforestry practices (adopters);
- Socio-economic characteristics: most interviewed farmers have not completely lost connection to past agroforestry practices and still maintain remnants;
- Attitudes: silvopastoral agroforestry practices and fruit production received highest scores regarding farmers' choice of practicing agroforestry;
- Perceived behavioral control: farmers expressed confidence in their decision making rights;
- Ecosystem-services: farmers attributed highest scores on habitat ecosystem services (both for livestock and wildlife), these are the most popular motivations for adopting agroforestry;
- Economic motivations: no opportunities can be reported on this variable, it obtained low scores;
- Subjective norms: both adopters and non-adopters expect that society would support a transition towards agroforestry practices.

On the other hand, the seven variables survey indicates the following challenges:

- Intention: Why did 48% of the interviewed farmers (non-adopters) express a negative intention to adopt or maintain agroforestry practices?
- Socio-economic characteristics: Why have farm trees lost their economic importance?
- Attitudes: How come that adopters and non-adopters believe that agroforestry is less productive than monoculture, in contradiction to scientific evidence?
- Perceived behavioral control: Why did non-adopters feel lack of confidence in the framework conditions and the management of agroforestry practices?
- Ecosystem services: Why were the regulation ecosystem functions provided by agroforestry, such as soil and groundwater protection, unknown to most farmers?

- Economic motivations: Why did adopters and non-adopters not perceive payments for ecosystem services as motivation for adoption? How can the marketing opportunities for tree products be enhanced?
- Subjective norms: Why did adopters and non-adopters expect that the farmers' community would not approve the adoption of agroforestry practices? Why did non-adopters expect negative reputational impacts in case they would adopt agroforestry practices?

Theme 3 puts forward past and present successful transdisciplinary collaborations which lead to the development and expansion of productive and diverse agroforestry systems. One is the "Streuobst" (intercropped orchard) success story in Europe, between the 1850s and the 1950s. The second is the Sahelian "Green Revolution" in the savannah parklands of West Africa, which is ongoing. A number of individual and institutional innovations were implemented in succeeding to co-restore degraded agricultural landscapes. The recommendations at the end of this chapter include the lessons from this chapter.

5.2 Discussion

5.2.1 Bio-economic challenges and opportunities

The results of the exploratory survey of the features and functions of Swiss farmers' innovations and the literature review yielded an inventory of living examples for the design of practicable and multifunctional agroforestry systems. Still, a lack of local knowledge on key ecosystem services potentially provided by Swiss agroforestry systems was found. It was therefore recommended to incorporate the concept of ecosystem services into the agricultural knowledge and economic system, to enhance the recognition of multifunctional farming systems. The need for valuating ecosystem services, as they usually have no markets, and the lack of valuation methods is also described by other studies (Daily and Ellison, 2002; Grêt-Regamey et al., 2008; Termorshuizen and Opdam, 2009; TEEB, 2010).

The bio-physical simulations indicate that the assessed Swiss agroforestry practices were more productive than the reference monoculture cropping systems (theme 1). Higher productivity of agroforestry compared to monoculture was also found in other European

countries (Graves et al., 2007; Van der Werf et al., 2007; Dupraz and Liagre 2008; Reeg, 2009). However, agroforestry practices can only be productive when synergies among the components can be realized and competition minimized. The aim is the 'application of ecological science to the study, design and management of sustainable agroecosystems' (Altieri 2002). Through the design of biodiverse landscape mosaics with various tree and crop species and varieties; to promote diet diversity and ecological economic resilience.
Hence, research is needed to explore best practice tree-crop combinations. Herby, a transdisciplinary approach is recommended to optimize synergies among the wide range of ecosystem services provided by agricultural landscapes (theme 1), and to meet local farmers expectations (theme 2). The success of agroforestry practices depends also on the marketing opportunities for the tree products and/or functions. Swiss agroforestry is likely to be unprofitable if the state of the art is not improved such as low tree product prices (Alder, 2007; Ferjany and Mann, 2007). On the other hand, the identified farmer innovations and the bio-economic assessment indicate that Swiss agroforestry can be economically competitive through innovative marketing of the tree products or through joining profitable ecological payment schemes. Payments for ecosystem services are critical to cover the high maintenance costs in Switzerland (Alder, 2007) and to discourage the felling of the remaining tress. We additionally recommend, as planting trees is a long term investment, to introduce establishment payments to create incentives for planting trees.
In contrast to these results, the seven variables survey revealed that Swiss farmers dislike payments for ecosystem services (theme 2).

5.2.2 Social challenges and opportunities

With regard to the assessment of Swiss farmers' behavior, the quantitative as well as the qualitative results confirm the presence of two knowledge systems among the farmers community (theme 2). One which is more open to the agroecological approach (adopters) and one which is closer to the agro-industrial approach (non-adopters), see also Chapter 1.1. Such opposing approaches to agriculture were also found by other studies, which suggest that they are often linked to specific knowledge systems (Roling and Engel, 1991). A knowledge system is a specific mental construct within specific actor networks. In the agricultural context such networks include consumers, farmers, extensionists, scientists, policymakers and, in the case of the agro-industrial approach, powerful agro-companies (Roling, 1996). The major differences identified between both farmer groups were of non-monetary nature, such as the significant differences in the reputation item. Remarkably, only adopters concluded that adopting agroforestry would have a positive impact on their reputation, in contrast to the non-adopters ($p<.01$). The results of this variable showed that the non-adopters' behavior is more oriented towards the opinion of their fellow farmers, which were expected to disapprove the idea of practising agroforestry (also by the adopters). In contrast, the adopters' behavior was found to be rather in line with the expectations of the society, which were expected (by both farmer groups) to highly welcome agroforestry practices.

These results indicate that the agro-industrial oriented farmers' perception is not in balance with the overall public consensus, despite the agreements in the 1990s for a transition towards multifunctional agriculture. These farmers no longer believe that food can be produced in tree-rich multifunctional landscapes. Their point is that they rather prefer to be food producers than to be (ecological) direct-payment receivers.

These findings indicate that the officially declared transition of Swiss agricultural policy towards multifunctionality has not yet reached the mainstream farmers community. One of the reasons is that the demands for ecological measures (i.e. ecosystem services) are not integrated in one farming system as suggested in Chapter 1 (Figure 1b). It is rather a conflict between production and other ecosystem services. In economic terms, as farmers still receive basic direct-payments, they do not see any reason to change, especially when there is a lack of feasible alternatives and agroecological knowledge.

Modern farmers need feasible alternatives and training to regain the fundamental ecological understanding that multifunctional farming systems can generate win-win situations. Examples of realizing synergies are farming systems that simultaneously enhance carbon sequestration in the soil, soil quality and profitability (Lal et al., 2010). Biodiverse farming systems such as agroforestry can provide various ecosystem services while increasing the stability of the basic food production system and decreasing the dependence on reducing external inputs (Altieri, 1999). Hence, Agroforestry can combine high productivity and food security with environmental services (Palma et al., 2007).

Hence, there is need for a more fundamental reform of the direct-payment system (Bosshard et al., 2010); as well as an update of research and farmer education towards the multifunctionality objective (Ewald & Klaus, 2009). A reform of the knowledge system would increase knowhow (perceived behavioral control) as well as raise the reputation of multifunctional farming systems such as agroforestry (subjective norms).

5.2.3 The potential of payments for ecosystem services

We started this thesis by asking whether an additional run for profits (i.e. payments for ecosystem services) can motivate to save our natural capital. The results of this study indicate that payments for ecosystem services have not been sufficient to change farmers' behaviour.

However, the bio-economic assessments also indicate the importance of payments for ecosystem services for the profitability of Swiss agroforestry. Especially, to kick-start investments into agroforestry systems which require 1-2 decades before producing enough fruits and even up to 60 years to produce high value timber. Still, the unanswered question remains: Can payments for ecosystem services be efficient in the continuous presence of payments for business as usual?

Furthermore, the results of the socio-ecological survey indicate various non-monetary barriers, and also found that most farmers are not interested in payments for ecosystem services. Reputation was identified as a potential social barrier for agro-industrial oriented farmers to adopt agroforestry practices.

The transdisciplinary success stories from Central Europe and the West African Sahel demonstrate how much effort is required to collectively improve agricultural landscapes. Farmers took initiative, collectively, and were supported by a wide range of scientific and real world stakeholders. With the objective to rehabilitate severely degraded natural resources, which were critical for their livelihood. This indicates that fundamental change is often the result of severe ecologic economic crisis. These success stories were not based on payments for ecosystem services. But rather through a fundamental reform of the political, social and natural capital. The shared awareness among the society facilitated collective action.

5.2.4 Transdisciplinary collaboration for positive change

We argue that research and landscape development concepts need to consider the diversity of local landscapes and the expectations of society. Theme 3 demonstrates how a culture of transdisciplinary collaboration can yield fruitful positive change. The successful transitions were based on fundamental scientific, technical and institutional innovations as well as effective governments and the empowering of local farmers (Lott, 1993; Reij et al., 2009). Constructive governments play an important role in facilitating sustainable food security (Keneally, 2011). Similar to the reviewed alternative green revolution which is ongoing in the West African Sahel, expansions of grass-roots movements are on the way in various other countries (Altieri and Toledo, 2011).

Traditional farming systems are examples of ecologically sustainable agroecosystems, and are often designed similar to the structure and function of local natural ecosystems (Gliessman, 2001). However, a successful transition of traditional agroforestry systems towards a modern scheme requires fundamental innovations. Including the creation of marketing opportunities for the products. These innovations are important in both, high-income-countries to sustainably mange remnants of cultural landscapes, as well as in smallholder dominated low-income-countries where traditional systems are still widespread and critical for food security.

Transdisciplinary research and development is a promising approach to support the co-production of shared visions and solutions (Hirsch Hadorn et al., 2008). For example the development of organic farming in Switzerland was facilitated by transdisciplinary co-production of knowledge (Aeberhard & Rist, 2009). The development of organic farming in Europe is a living example of realizing win-win solutions. The increased demand for healthy food by consumers facilitated the expansion of organic farming. This example suggests that sustainable agricultural development is a matter of collective action. The following individual and institutional innovations are suggested to facilitate a more effective transition towards a multifunctional and tree-rich agriculture:

1. *Consumers* are decisive, as their consumption behavior has far reaching effects. For example, buying of products from traditional orchards contributes to the survival of standard trees, which are popular (Schüpbach et al., 2010). The consumer perceptions of "green" farming need to be further explored (Gomez et al., 2011).
2. *Scientists* play a key role, as a wide range of social, economic and agro-ecological research is needed to co-develop productive and multifunctional agroforestry systems. For example, there is a lack of agroforestry field experiments in Switzerland, to explore suitable tree-crop combinations. The ecosystem services concept is a promising basis for holistic landscape assessment (Grêt-Regamey et al., 2008; Termorshuizen and Opdam, 2009; TEEB, 2010).
3. *Education & extension experts* are indispensable to address communication constraints and limited access to information (Wettasinha and Waters-Bayer, 2010), giving equal priority for agro-industrial as well as agroecological approaches (IAASDT, 2009).
4. *Policymakers* are fundamental for the design of policies that reduce conflicts between individual interests; remove barriers towards sustainable ecosystem management such as opportunity costs (Ghazoul, 2008); and empower local governance. There is need for the implementation of the ecosystem services concept into agricultural and landscape development concepts (Staub et al., 2011). Last but not least, more funds for agroforestry research is critical.
5. *Farmers* play the most important role in shaping agricultural landscapes and need to be considered in research and development activities (Reij et al., 2009). Their responsibilities include providing food security, reducing environmental impacts and creating multifunctional landscapes. As indicated by this thesis, these are major challenges which require a wide range of monetary and non-monetary support.

5.3 Conclusion

This thesis identified bio-economic and social opportunities and uncertainties, on the way to rehabilitate Swiss agroforests. With regard to the long establishment phase, the introduction of establishment payments to motivate tree planting is recommended (theme 1). It can also be confirmed that the increased levels of direct-payments for standard trees are important to support farmers to cover the high maintenance costs. However, despite increasing direct-payments, mainstream Swiss farmers still resist adopting agroforestry practices and farm trees are still declining. Competitive direct-payments for business as usual as well as non-monetary barriers such as reputational risks, resistance against ecological payments or lack of knowledge may explain why payments for ecosystem services have not been more successful to change farmers' behavior (theme 2).

Hence, beside payments for ecosystem services, the recovery of marketing opportunities for fruits seems to be the more sustainable way to encourage farmers to plant trees. At the same time, the co-production of agroecological knowledge needs to be promoted, to enhance the popularity of ecological approaches and to empower farmers to develop agroecological win-win solutions. The participation of farmers in the landscape development process is important (theme 3), as a top-down approach may not result in improved understanding but in social resistance.

This transdisciplinary thesis aimed to contribute to Swiss agroforestry research, which is still neglected compared to mainstream monoculture research. However, the co-developed scenarios were based on model estimations and the surveys covered a limited number of persons. Additionally, only few agroforestry practices were assessed, despite the existence of diverse options to develop locally adapted agroforestry practices. Hence, field experiments are required to further validate available models and a wide range of disciplinary and transdisciplinary research is needed to co-develop tree-rich agricultural landscapes. One step has been taken by the agricultural research station Agroscope Reckenholz-Tänikon (ART), through founding of a national multistakeholder platform (www.agroforst.ch; www.agroforesterie.ch).

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Appendices

Information material and main questionnaire for the seven-step-survey

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(German Version)

Bäume und Kulturen - eine sinnvolle Doppelnutzung?

Fragen zum Interview mit Landwirten

Betrieb: …………………………………………………………	Ort, Datum………………………………

Einleitung

Im Rahmen des BAUMGÄRTEN Projekts beschäftigen wir uns mit dem Rückgang von Hochstamm- Bäumen in der Kulturlandschaft der Schweiz.
Das Ziel ist die Erforschung von Anbausystemen mit Hochstamm-Bäumen, welche nicht nur interessant für die Natur sind, sondern auch für die Landwirte.
Daher interessieren wir uns für Ihre Meinung zu dem Thema: Bäume und Kulturen - eine sinnvolle Doppelnutzung für die heutige Landwirtschaft?

- Die Auswertung der Ergebnisse erfolgt anonym.
- Wir sind an Ihrer persönlichen Meinung interessiert, daher gibt es keine richtigen oder falschen Antworten.

Unter Baumgärten oder Agroforstwirtschaft verstehen wir: Die Nutzung einer Fläche mit Bäumen kombiniert mit Kulturen (oder Beweidung)

Wir hatten Ihnen kürzlich **Infomaterial** zugeschickt. Die meisten folgenden Fragen werden sich auf die dort beschriebenen 5 Baumgärten Optionen beziehen.

Infomaterial

(Grundlage für die Fragen über die Agroforstsysteme)
Im Folgenden unterscheiden wir **5 Optionen**, um Baumreihen in landwirtschaftliche Flächen zu integrieren:

1. **Baumhecken**
2. **Alleen**
3. **Streuobst-Wiesen** (gemäht oder beweidet)
4. **Streuobst-Äcker**
5. **Waldweidesysteme**

Baumreihen in Form von Windschutzhecken oder als Alleen (System 1 und 2)

Die einfachste Möglichkeit ist Bäume in Form einer **Heckenlandschaft oder Alleen** an den Feldrändern zu pflanzen.

System 1: Baumhecken

System 2: Baumreihe als Alleen

(photo: Pro Natura)

Streuobst-Wiesen (System 3) (gemäht oder beweidet)

Zur Kategorie der Streuobst-Wiesen zählen die **traditionellen Hochstamm-Obstgärten**. Diese heute noch anzutreffenden Agroforstsysteme kombinieren Hochstamm-Bäume mit einer beweideten oder gemähten Streuobstwiese.

(photo: http://www.montpellier.inra.fr/safe)

Streuobst-Äcker (System 4)

Die Streuobstnutzung von Hochstamm-Bäumen kombiniert mit Ackerkulturen sind heutzutage - abgesehen von ein paar alten belassenen Bäumen - kaum mehr in der Schweiz anzutreffen.

(photo: http://www.montpellier.inra.fr/safe)

(photo: Alexander Möndel)

Waldweidesysteme (System 5)

Auch die **Waldweide** gilt als ein problematisches Auslaufmodell. Seit jedoch die Vorteile dieser alten Kulturform wiederentdeckt werden, nimmt die Popularität der Waldweide in manchen Regionen wieder zu.

(photo: Andrea Mayer)

Bäume und Kulturen - eine sinnvolle Doppelnutzung?

Was meinen Sie dazu?

Fragebogen

A. Damit wir Ihren Betrieb besser kennen lernen, bitten wir Sie um ein paar Angaben zum Betrieb

Socio-economic characteristics

1. Angaben zum Betrieb

a) Landwirtschaftliche Betriebsgrösse (ha):

< 5	5-10	10-20	> 20 ha
☐	☐	☐	☐

Pachtland b) Wie hoch ist der Anteil zu gepachteter Fläche an der Gesamtfläche?				
Pachtland in %	<25	25-50	50-75	75-100
	☐	☐	☐	☐

Produktionsschwerpunkte c) Wie wichtig sind die folgenden Betriebszweige in Ihrem Betrieb	gar nicht			sehr hoch
	1	2	3	4
Ackerbau	☐	☐	☐	☐
Grünland	☐	☐	☐	☐
Tierhaltung	☐	☐	☐	☐
Waldbewirtschaftung	☐	☐	☐	☐
Obstproduktion	☐	☐	☐	☐
Weinbau	☐	☐	☐	☐

d) Betriebstyp: ☐ ÖLN ☐ Bio

e) Bewirtschaften Sie den Betrieb im ☐ Haupterwerb oder ☐ Nebenerwerb

2. Angaben zur Person

a) Geschlecht: ☐ weiblich ☐ männlich

b) Alter: ☐ < 20 ☐ 20-40 ☐ 40-60 ☐ > 60 Jahre

c) Ausbildung: ☐ keine formale Ausbildung ☐ Landwirtschaftsschule ☐ Meisterprüfung ☐ FH/Universität
☐ Sonstige…………………………………

d) Ist die Nachfolge Ihres Hofes gesichert?
☐ Ja ☐ Nein

B. Baumgärten (Agroforstwirtschaft) - früher und heute
(Bezieht sich auf Infomaterial)

3. Gab es früher Baumgärten in Ihrem Betrieb?

☐ Nein ☐ Ja Wenn Ja, welche Systeme *(Bilder Infomaterial)*:

(Offene Frage: Bitte ausfüllen & ergänzen)

Baumgärten: früher	
Baumreihen als…	
1. Baumhecken	☐
2. Alleen	☐
3. Streuobst-Wiesen	☐
4. Streuobst-Äcker °	☐
5. Waldweidesysteme	☐

°Ackerkulturen:
………
……
……………

4. Befinden sich <u>heute</u> noch Hochstammbäume in Ihrem Betrieb?

☐ Nein ☐Ja
<u>Wenn Ja:</u>

Anzahl Bäume: ……………………………………………………………………………..

Welche Systeme: ☐1 ☐2 ☐3 ☐ 4 ☐ 5

Welche Baumarten sind am häufigsten:
……………………………………………………………………………………………………
…………………………………………

C. Baumgärten Optionen für eine sinnvolle Doppelnutzung

Attitude/ Preference

Optionen für die Nutzung der Bäume

5. Welche Baumprodukte würden Sie interessieren?	NEIN gar nicht	fast gar nicht	eher nicht	eher ja	fast sicher ja	JA sehr
	1	2	3	4	5	6
Obstproduktion (normaler Hochstamm)	☐	☐	☐	☐	☐	☐
Edelholz (aufgeastet, wie ein Waldbaum)	☐	☐	☐	☐	☐	☐
Energieholz (Kurzumtrieb[1])	☐	☐	☐	☐	☐	☐

[1]Energieholz (Kurzumtrieb): schnell wachsende Baumarten wie Pappeln, der Aufwuchs wird energetisch als Hackschnitzel oder stofflich als Zellstoff verwertet, die Bäume werden alle drei bis zehn Jahre geerntet

6. Gibt es Baumarten die Sie besonders interessieren würden?
Nein: ☐
Ja: ☐
………

Baumgärten Optionen für eine Doppelnutzung *(Bezieht sich auf Infomaterial)*

7. Wie gefallen Ihnen die folgenden Optionen für eine sinnvolle Doppelnutzung? (auch wenn nicht realistisch für Ihrem Betrieb) *Bewertung: von 1=sehr schlecht, bis 6 = sehr gut (wie in der Schule)*	sehr schlecht					sehr gut
	1	2	3	4	5	6
Baumreihen als…						
1. Baumhecken	☐	☐	☐	☐	☐	☐
2. Alleen	☐	☐	☐	☐	☐	☐
3. Streuobst-Wiesen	☐	☐	☐	☐	☐	☐
4. Streuobst-Äcker °	☐	☐	☐	☐	☐	☐
5. Waldweidesysteme	☐	☐	☐	☐	☐	☐
Andere Baumgärten Optionen die Ihnen gefallen:						
…………………………………………						
…………………………………………						

°*Ackerkulturen:*……………………………………………………………………………………………
………….

D. Chancen und Herausforderungen der Doppelnutzung

Attitudes

8. Welche der folgenden Punkte sind eher Stärken oder Schwächen der Agroforstwirtschaft? Inwieweit stimmen Sie den folgenden Aussagen zu oder nicht zu: Diese Art die Fläche doppelt zu nutzen empfinde ich als....	trifft gar nicht zu	trifft fast gar nicht zu	trifft eher nicht zu	trifft eher zu	trifft fast voll zu	trifft voll zu
	1	2	3	4	5	6
Betriebswirtschaft						
…weniger riskant wegen Einkommensausfällen (Doppelnutzung in Vergleich zur Monokultur)	☐	☐	☐	☐	☐	☐
…einfach zu bewirtschaften (Fachwissen vorhanden)	☐	☐	☐	☐	☐	☐
Landwirtschaftliche Produktion						
…interessant für hohe Produktivität (Erträge: Baum + Unternutzen)	☐	☐	☐	☐	☐	☐
…geringe Konkurrenz für die Unterkultur	☐	☐	☐	☐	☐	☐
…gut vereinbar mit der Mechanisierung	☐	☐	☐	☐	☐	☐
Andere wichtige Eigenschaften, die Ihnen wichtig sind:						
…………………………………………						
…………………………………………						
…………………………………………						

E. Motivation

Welche der folgenden Punkte sprechen für oder gegen das Pflanzen von Hochstammbäumen auf landwirtschaftlich genutzten Flächen? Inwieweit stimmen Sie den folgenden Aussagen zu oder nicht zu?

9. Hochstammbäume zu pflanzen empfinde ich als....	trifft gar nicht zu	trifft fast gar nicht zu	trifft eher nicht zu	trifft eher zu	trifft fast voll zu	trifft voll zu
	1	2	3	4	5	6
Betriebswirtschaft				*Economic Motivations*		
…interessant wegen der Wirtschaftlichkeit	☐	☐	☐	☐	☐	☐
…interessant wegen den jährlichen Beiträgen	☐	☐	☐	☐	☐	☐
…bedeutungsvoll für die Selbstversorgung	☐	☐	☐	☐	☐	☐
10. Hochstammbäume zu pflanzen empfinde ich als wichtig....				*Ecological Motivations*		
…als Windschutz	☐	☐	☐	☐	☐	☐
…als Schatten für Tiere	☐	☐	☐	☐	☐	☐
…für die Erhaltung der Kulturlandschaft	☐	☐	☐	☐	☐	☐
…für die Artenvielfalt (z.B. Vögel)	☐	☐	☐	☐	☐	☐
…als Bodenschutz gegen Erosion	☐	☐	☐	☐	☐	☐
…als Grundwasserschutz (z.B. Nitrat)	☐	☐	☐	☐	☐	☐
Andere wichtige Eigenschaften, die Ihnen wichtig sind:						
…………………………………………						
…………………………………………						

F. Sozioökonomische Rahmenbedingungen

Rahmenbedingungen für die Doppelnutzung	NEIN gar nicht	fast gar nicht	eher nicht	eher ja	fast sicher ja	JA sicher
	1	2	3	4	5	6
						Intention
11. Würden Sie heute wieder Hochstammbäume pflanzen um Teile Ihrer landwirtschaftlichen Flächen doppelt zu nutzen?	☐	☐	☐	☐	☐	☐
						Subjective norms
12. Wer würde die Doppelnutzung befürworten?						
…die Landwirte in Ihrer Umgebung	☐	☐	☐	☐	☐	☐
…die landwirtschaftliche Beratung	☐	☐	☐	☐	☐	☐
…die landwirtschaftliche Forschung	☐	☐	☐	☐	☐	☐
…die Landwirtschaftspolitik (Direktzahlungen)	☐	☐	☐	☐	☐	☐
…die Bevölkerung	☐	☐	☐	☐	☐	☐
…die Naturschützer	☐	☐	☐	☐	☐	☐
13. Das Pflanzen von Hochstammbäumen auf landwirtschaftlich genutzten Flächen, empfinde ich als wichtig für das Ansehen meines Betrieb	☐	☐	☐	☐	☐	☐

Perceived behavioral control

Inwieweit stimmen Sie den folgenden Aussagen zu oder nicht zu?	trifft gar nicht zu	trifft fast gar nicht zu	trifft eher nicht zu	trifft eher zu	trifft fast voll zu	trifft voll zu
	1	2	3	4	5	6
14. Die Entscheidung Hochstammbäume zu pflanzen und meine Flächen doppelt zu nutzen liegt allein bei mir	☐	☐	☐	☐	☐	☐
15. Die Rahmenbedingungen erlauben es mir gut meine Flächen doppelt zu nutzen	☐	☐	☐	☐	☐	☐
16. Eine sinnvolle Doppelnutzung ist für mich einfach zu bewirtschaften	☐	☐	☐	☐	☐	☐

Knowledge & Interest

Wissen/ Beratung	sehr wenig					sehr hoch
	1	2	3	4	5	6
17. Finden Sie, dass über die vielen Optionen der Agroforstwirtschaft genug informiert wird?	☐	☐	☐	☐	☐	☐
18. Wie hoch schätzen Sie Ihre Kenntnisse ein?	☐	☐	☐	☐	☐	☐
19. Würde Sie ein Besuch von Betrieben mit Agroforstsystemen interessieren?	☐	☐	☐	☐	☐	☐
20. Möchten Sie weitere Informationen zur Agroforstwirtschaft erhalten?	☐	☐	☐	☐	☐	☐

Ökologische Direktzahlungen

21. a) Wie hoch ist der maximale Beitrag für Hochstammbäume in Ihrem Kanton?

- ☐ nicht sicher
- ☐ ………CHF/Baum/Jahr

b) Erhalten Sie Beiträge für Hochstammbäume?

- ☐ Nein
- ☐ ………CHF/Baum/Jahr

Attitudes

Ökologische Direktzahlungen	NEIN gar nicht					JA sehr
	1	2	3	4	5	6
c) Finden Sie, dass die heutigen Beiträge für Hochstammbäume ausreichend sind?	☐	☐	☐	☐	☐	☐

Agrarlandschaft

22. Wie würden Sie die Agrarlandschaft in Bezug auf Hochstammbäume bewerten?
Inwieweit stimmen Sie den folgenden Aussagen zu oder nicht zu?
Es befinden sich ausreichend Hochstammbäume in …

… den Agrarlandschaften der Schweiz?	☐	☐	☐	☐	☐	☐
… der Agrarlandschaft meiner Gemeinde?	☐	☐	☐	☐	☐	☐

Haben Sie noch andere Fragen oder Bemerkungen?
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

Danke viel mal für das Interview!

Acknowledgements

Without the great support from numerous people it would not have been possible to organize and realize this transdisciplinary PhD project. Among the many I want to mention a few.

First and foremost I would like to thank my main supervisor Felix Herzog (ART). Thanks for your consistent and constructive support throughout the thesis, and for your availability (not only during official working hours). It was a great pleasure to work with you.

Special thanks also to my supervisor at ETH-Zurich Prof. Jaboury Ghazoul for giving me this excellent opportunity to conduct my thesis within your supportive research group.

Thank you Prof. Bernard Lehmann for being my co-supervisor and Prof. Georg Cadisch for being my external examiner.

I would also like to thank Anil Graves, Jean-Pierre Sorg, Dunja Dux, Ann Waters-Bayer, Martin Dobricki and Joao Palma for their scientific support and inputs.

Many thanks to many colleagues at ART for providing me perfect working conditions. Including regular sport activities (thank you coach). A special recognition goes to Jerylee Wilkes, Alexandra Kaeser and Erich Szerencsits for their help during the nationwide survey.

Similarly, I am grateful to the ETH-Zurich staff for managing the administrative issues of my PhD, and to my friendly colleagues (e.g., thanks for showing me the beauty of Swiss mountains Ernest and Thomas).

I am grateful to the people in the accompanying expert groupe, Barbara Stäheli, Patricia Steinmann, Yvonne Reisner, Urs Müller, David Szalatnay, and Ueli Rehsteiner, for their scientific and practical advices.

Unique thanks are also dedicated to the farmers for their valuable time, and allowing me to profit from their broad knowledge and experiences. Especially to the innovative Swiss farmers like Edi Hilpert.

This thesis would not have been possible without the financial support from the MAVA foundation, to which I'm very thankful.

My deepest thanks goes to my family for their motivation. Thanks to my parents (Ilen and Sereke), sister (Eden), brothers (Dawit and Bereket) and to my other relatives. I hope to have more time for you now, especially for my daughter Salome.

Last but not least, thanks to God for guidance and protection, as "faith can move mountains".