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Analysis

The Case of Legume-Cereal Crop Mixtures in Modern Agriculture and the Transtheoretical Model of Gradual Adoption

Dominic Lemken [a,*], Achim Spiller [b], Marie von Meyer-Höfer [b]

[a] Centre of Biodiversity and Sustainable Land Use, University of Goettingen, Platz der Göttinger Sieben 5, 37073 Göttingen, Germany
[b] Department of Agricultural Economics and Rural Development, University of Goettingen, Platz der Göttinger Sieben 5, 37073 Göttingen, Germany

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ABSTRACT

Mixed cropping (MC), the growing of two or more coexisting crops in one field, specifically the mix of cereal and grain legumes, can contribute to a more sustainable agricultural land use. Despite a variety of ecological benefits and promising grain productivity, applications are scarce among farmers in developed countries. In consideration of MC's potential this study interviews farm managers to profile characteristics of adopters. The transtheoretical model (TTM) is applied to capture adoption and adoption tendencies. The results point to a significant positive role of land owned vs. leased, adoption of reduced tillage and adoption intensity of legumes in general. The perception of technical barriers and the perception of MC's usefulness are also major drivers that proponents need to address. In general, the TTM provides a gradual measure of farmer's willingness to adopt, leading to more variance than binary classifications, which makes TTM especially useful to adoption research of marginalized ecological practices.

1. Introduction

The Food and Agriculture Organization of the United Nations (FAO) promotes conservation agriculture to reduce dependence on chemical inputs and diminish eutrophication. Conservation agriculture (CA) builds on three principles: the continuous minimum mechanical soil disturbance, the permanent organic soil cover and the diversification of crop species grown in sequences and/or associations (FAO, 2016). The latter, associated crop mixtures, is often considered suitable only for developing country settings with low labor costs. Nevertheless, industrialized and mechanized "mixed cropping" (MC) approaches are available, although rarely connected with CA-methods.

Noteworthy, the term "Mixed Cropping" created confusion outside the plant scientific community. Agriculture economists tend to understand it as a mix of cropping and livestock on a farm. The term "Intercropping" can create an image of agriculture without the opportunity for a mechanized farm management with combine harvesters etc. A less practical but distinctive term may be "industrialized crop mixtures" or "legume-cereal crop mixtures in modern agriculture". So practicing MC i.e. growing two or more main crops in one field simultaneously, can help to design a sustainable agriculture cropping system, because it reduces the need for exhaustible resources. A mixture of grain legumes and cereals has been found to improve the biological pest management (Hauggaard-Nielsen et al., 2008; Malézieux et al., 2009; Hiddink et al., 2010; Pan and Qin, 2014; Wezel et al., 2014; Vrignon-Brenas et al., 2016), reduce synthetic fertilizer needs (Malézieux et al., 2009; Wezel et al., 2014; Vrignon-Brenas et al., 2016) and thereby diminishes risks associated with chemical input use (Thornton, 2000; Malézieux et al., 2009). Politically this advantage will gain in salience. Germany's upcoming reform of synthetic fertilizer use will tighten legislation in favor of alternative fertilization methods (BMEL, 2016). Additionally, such mixtures go hand in hand with a drought resistant, due to an increased water use efficiency (Wang et al., 2015) with less eutrophication of water courses (Malézieux et al., 2009) and a reduced risk of soil erosion (Betencourt et al., 2012). The output productivity of mixtures, in terms of grain production per acre, is higher than in mono stands, although research is only conclusive on mixtures vs. mono stand in low input agricultural systems (Brooker et al., 2015; Duc et al., 2015). The enhanced field diversity and the enhanced associated biodiversity (Malézieux et al., 2009) can satisfy public demands respectively and present a path to reduce mono-cropping in modern agriculture.

On the contrary, MC imposes new technical obstacles and lacks knowledge relevant to ensure an efficient implementation, so that MC is still poorly integrated with agriculture (Wezel et al., 2014). Mixtures require the coordination of the maturity of two or more crops, a novel variety selection and a diversified depth in seed drilling. Farmers also face technical hurdles, as they need to separate the MC harvest crops in order to fully utilize their value. The sieving process of MC-crops is not part of the farmer's standard workflow. On-farm experience with

* Corresponding author.
E-mail addresses: dlemken@gwdg.de (D. Lemken), a.spiller@agr.uni-goettingen.de (A. Spiller), marie.von-meyer@agr.uni-goettingen.de (M. von Meyer-Höfer).

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mixtures would increase transparency on the barriers regarding knowledge and technical risks. Such obstacles root deep into the science and technology landscape of agriculture. The breeding of seed varieties, the design of agriculture machineries, the extension services, best practice recommendations, plant protection and more; most agricultural progress evolves around mono stands. For decades incremental innovations have enhanced productivity and efficiency of mono stands. Multi-cropping systems were hardly developed. This research gap creates a technological “lock in” to mono-stands,[1] meaning the path of technological progress is built around a specific system, e.g. mono stands, not because the performance is necessarily better, but it is difficult or costly to escape from this path (Perkins, 2003). Considerable investments would be necessary to optimize production factors of mixtures. Up until now research on mixtures is rare (Duc et al., 2015), especially socio-economic research. Efforts by agronomists, to analyze the relative MC-advantages, are just beginning to counter the research lock-in.

Research limitations present an economic risk for farmers who switch field management from mono- to multi-cropping systems. Farmers have to deal with all challenges involved. They cannot rely on extensive performance reports of crop varieties or specialized agriculture machinery to reduce the work load. Subsidy payments have not been established. Currently, political support schemes incentivize pure legume cropping for their ecosystem services, e.g. within the greening obligations of the EU's common agriculture policy (CAP), but the MC-fields are treated as just another crop in the farm portfolio (BMEL, 2015). Conclusively, in economic terms, MC needs to compete with the profitability of pure cereal stands and a lack of socio-economic research hinders a concrete and transparent economic assessment. So MC adoption is marginal among farmers. E.g. in Germany the adoption is limited to 88,300 ha which accounts for 0.007% of all land distributed to cropping (AMI, 2014). Compared to 84,600 ha in 2011 MC has experienced subtle growth, but from a macro perspective the diffusion process is still in its infancy.

While conservation practices, like conservation tillage, no-tillage, cover crops and others, have become salient in farm adoption research (Knowler and Bradshaw, 2007), adoption research has so far neglected the marginalized MC approach. The identification of early adopters holds considerable value for the diffusion of an innovation (Schreier et al., 2007). Such early adopters can also help to optimize a technology. Farm trials and their MC related needs may contribute to a more efficient implementation in different cropping environments and thereby enrich the research on MC. Additionally, they involve farmers in innovation development processes and encourage participatory processes (Edwards et al., 1993; Pannell et al., 2006). A significant fraction of innovations is directly initiated by the needs and specific requests of users (Lüthje and Herstatt, 2004). The early adopters may foresee new or future needs of the market significantly earlier than the majority (Lüthje and Herstatt, 2004). Possibly MC-advantages can be used to communicate an additional value of farm products to consumers or offer a flexible approach to enhance legume cropping to comply with stricter regulations on synthetic fertilizer use or soy imports. The profile of early adopters is also valuable to agribusinesses that provide products or extension services related to MC. If the adopter profile underlies a trend to expand or diminish, then such profile information provides some outlook on the potential of MC's diffusion.

Typically, agricultural research uses nominal classifications for adoption (Knowler and Bradshaw, 2007). In the case of MC, recalling the technological and economical challenges, adoption levels are comprehensible low. Binary classifications do not capture the willingness to adopt a multi-cropping system, but only reflect the current farmer's opinion on the best choice for the farm. We propose the transtheoretical model (TTM), which can account for gradual adoption tendencies. TTM is designed to analyze the progress of an individual in changing a specific behavior (Prochaska and Velicer, 1997). The multiple adoption stages enlarge the statistical variance, valuable to marginalized innovations that could otherwise not be modelled.

We expect attitudes towards MC and perceptions of technical barriers will differ significantly along the stages of the adoption process. Further we hypothesize that crop management, farm and farm manager's characteristics vary significantly from adopters to non-adopters. The selected characteristics are common to CA-adoption research. Such properties guide an identification of early adopters. An empirically study of farmers is used to test these assumptions and bring out relevant properties. Hence, we interviewed via telephone a sample, geographically representative in Germany, and analyzed it with the means of a proportional odds model. The limitations of the research design are directly stated in the context of the results. The findings are discussed with CA-adoption literature. Conclusions follow.

2. Materials and Methods

2.1. Survey Design

2.1.1. The Transtheoretical Model and Mixed Cropping Adoption

In consideration of the technological lock-in to monocrops, that we have discussed, we need to recognize the perceived change that a mixed cropping system imposes on farmers. MC cannot be added to mono stands, but is a technology competing for adoption. Adoption models have considered the relative advantage of one technology over alternatives among other drivers (Rogers, 2010). The transtheoretical model (TTM) for behavioral change is even more concerned with the rethinking of the current behavior (Prochaska and Velicer, 1997). Although TTM was designed to track personal changes of deeply rooted behavior related to health choices, like smoking, rather than agricultural matters, TTM has also been useful to analyze a psychological change with respect to environmental behavior (Tobler et al., 2011). In similar fashion TTM can analyze farmer's intention to change an established behavior and switch from mono-cropping to mixed cropping. The model provides additional insights into the gradual stage of change that can be interpreted as adoption tendencies. The feature is especially useful to analyze practices where final adoption is rare, so that minimal variance of the adoption parameter could otherwise endanger a meaningful statistical analysis.

The stages of the TTM capture the gradual attitude from rejecting a behavioral change to adopting it. TTM verbalizes the outcome of each individual evaluation of the pros and cons of changing, so a farmer chooses a stage based on what is most appropriate to describe his/her stage of adoption. The four stages can be summarized and have been operationalized similar to Tobler et al.'s (2011) application in the food sector (Table 1).

Table 1
The transtheoretical model to adopt Mixed Cropping.

Stage	Concept	Operationalization
Precontemplation	no intention to change, lack of motivation or information to change	“I am not willing to trial MC”
Contemplation	intention to change, still considering associated costs and benefits	“I am generally willing to trial MC, but do not know how”
Preparation	intention to change with a concrete plan of action	“I look forward to trial MC and know where to start”
Action	behavior has changed	“I work with MC in my crop rotations”

[1] In connection to the briefly outlined lack of innovation, Vanloqueren and Baret (2009) describe institutions and a paradigm of the agriculture technology regime that locks out agroecology. They present a paradigm of reductionism that evolves contrary to complex cropping systems. MC, which builds on agroecological principles, may or may not be affected by the paradigmatic lock out.