Land Use Policy 80 (2019) 163–174

Contents lists available at ScienceDirect

Land Use Policy

journal homepage: www.elsevier.com/locate/landusepol

Exploring the adoption of precision agricultural technologies: A cross regional study of EU farmers

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ARTICLE INFO

Keywords:
Precision Agriculture
Random Intercept Logistic Regression
EU Policy

ABSTRACT

Precision agricultural technologies (PATs) allow more detailed management of in-field variability. Policy and advisory communities have championed PATs as a route to preserving natural capital whilst increasing productivity from agricultural land. A range of PATs are currently available for the agricultural producer but uptake varies by the type of technology and region. Whereas most studies on uptake have focused on US or Australia we empirically examine uptake of machine guidance (MG) and variable rate nitrogen technologies (VRNT) within European farming systems. Using primary information from 971 arable crop growers across five countries: Belgium, Germany, Greece, the Netherlands and the UK, a multilevel random intercept regression estimated a) the differences between adoption and non-adoption and b) the differences between VRNT and MG adoption. We find, aside from size and income differences, which reflect the economic cost barrier to adoption, an attitudinal difference, in terms of optimism towards the technology's economic return leading to more probability of uptake. Moreover innovative and information seeking behaviour also proved significant when upgrading from machine guidance to variable rate technologies. Subsidy and taxation were considered positive drivers of uptake within the community. However, results suggest that more indirect interventions, such as informational support to counteract industry bias, and demonstration to prove the viability of economic return may be effective at meeting land manager and policy expectations towards PATs.

1. Introduction

The prescient need for sustaining soil quality to maintain and extend productivity potential, whilst simultaneously supporting a range of ecosystems services, makes precision farming a possible pathway for meeting global ambitions towards food security (Gebbers and Adamchuck, 2010; Telabpour et al., 2015). Precision agricultural technologies (PATs) are a set of technologies that are aimed at the management of in-field heterogeneity (Stafford, 2000; Fountas et al., 2005; Reichardt and Jurgens, 2009; Aubert et al., 2012). A range of benefits have been aligned with the uptake of PATs and these have focused on improved resource use productivity, reduced input usage and cost, in particular labour and management time, with wider associated benefits from targeted application of agrochemicals and nutrients (Godwin et al., 2003; Silva et al., 2011; Kindred et al., 2015; Smith et al., 2013; Eory et al., 2015; Schimmelpfennig, 2016). PATs have been in development for the last 3 decades, since the commercialisation of global positioning systems, and we can identify four differing technological hierarchies of PATs (Fig. 1).

These hierarchies imply different levels of user engagement and, by implication, the requisite farmer or operator skill and acquired learning needed to operate these technologies. A number of authors identify two major types of user engagement, based on their level of interaction and the learning investment needed by the operator (Griffin et al., 2004; Daberkow and McBride, 2003; Popp et al., 2002; Miller et al., 2017). They identify '*embodied knowledge technologies*' which require no

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https://doi.org/10.1016/j.landusepol.2018.10.004
Received 27 November 2017; Received in revised form 27 August 2018; Accepted 1 October 2018

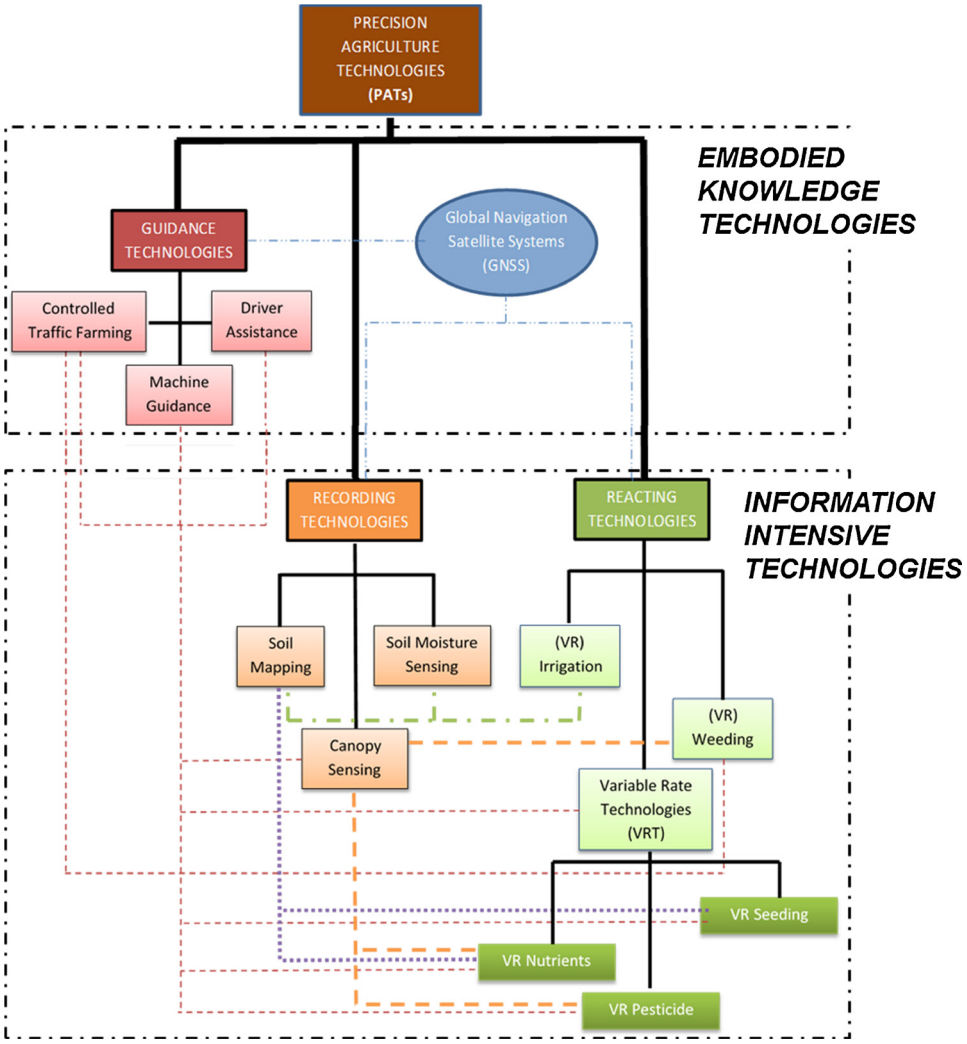

Fig. 1. Hierarchy of Precision Agricultural technologies.
Source: modified from Balafoutis et al. (2017).

additional skills for their operation, for example automated guidance systems which allows precise control of machinery in the field; and '*information intensive technologies'* which provide additional information that offer insights for decision making, but also require further investment, in terms of knowledge, software or analytical service support for data analysis, for example from variable rate application technologies.

The attraction to policy makers of PATs within the farming community is that they may allow a step change in productivity to meet food supply requirements under land constraints and an increased desire for environmental monitoring (Zarco-Tejada et al., 2014; Schrijver et al., 2016). The current policy framework for PATs, and precision farming generally, is diffuse. Schrijver et al. (2016) outline potential European policies which are affected or may have to change to accommodate adoption of PATS. These include environmental regulations and directives focused on air, carbon and water pollution; regional policy which accommodates both the integration of broadband and mobile data networks in rural and remote rural regions; and the potential for alternative employment within these communities from on-farm PAT adoption. Moreover, a whole tranche of industry wide policies, pertaining to food traceability, data access and storage, and intellectual property rights have to evolve if PATs are to become an intrinsic part of the fabric of future European farming. More indirect drivers, through tightening of the Nitrates directive, may encourage some farmers to use N-efficient agronomic measures or technologies, such as variable rate nitrogen applicators. Similarly, if policy shifts towards rewarding public goods generation then payment mechanisms may incentivise organisation and collection of environmental data for basing payment rates (Barnes et al., 2011a,b; Helm, 2017).

PATs also challenges the farming population to change working practices, requires high initial capital investment and added maintenance costs. A range of services from different consultancies have emerged which are allied to farming and provide analysis of the intensive data collected by PATs and related satellite imaging technologies. This diversity of service provision might have a lock-in effect due to, for example the incompatibility between different components of PATs and, consequently, negatively affect the uptake of PATs (Aubert et al., 2012; Robertson et al., 2007). A further set of barriers emerge from the regulatory, technological and policy environment which may provide restrictions, e.g. on unmanned aerial vehicles or access to internet based services in remote rural regions, which hamper uptake for particular members of the farming community (CSA, 2015).

The aim of this paper is to understand the internal and external determinants of the adoption of PATs within a European cross-country setting. The first objective is to analyse the characteristics behind non-adoption compared to adoption of PATs, in order to assess the potential barriers towards uptake. Secondly, we assess the characteristics across an adoption transition, from an 'embodied knowledge' technology to an 'information intensive' technology. In so doing we aim to understand the institutional drivers behind greater uptake of PATs. This assessment will allow us to provide insights for future interventions of agricultural