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Short Research Communication

UK agriculture policy and intensification since the 1970's: Assessing environmental consequences due to fertilizers, pesticides, and hedgerow management

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Henry Williamson's documentary 'The Vanishing Hedgerows' illustrates increasing environmental problems from agricultural intensification in the UK. Almost half a century later, these concerns continue despite transitions toward sustainable intensification and political conservation agendas. Domestic application rates for artificial pesticides continue to increase, causing additional stress for non-target species. While nitrate fertilizer applications have declined, eutrophication, deposition and acidification remain which suggests possible environmental accumulation. Mechanized management of hedgerows is common practice, affecting local habitat structures and environmental services. In response to these multi-variant problems, the UK government has implemented stringent environmental regulations. This includes promotion of traditional management, investments in agricultural technologies, and payments for ecosystem services. This paper reviews the extent to which these policies have been successful in addressing environmental concerns from agricultural intensification. Analysis takes on a geographic perspective, trying to make sense of the diverse spatial spread of policy uptake. It is concluded that the net results of policy interventions are ambiguous, since environmental problems are still prevalent across different spatial contexts. It is further concluded that examples of localized success may be more closely related to general trends of land abandonment in lowland areas, and not policy effectiveness.

Key words: UK, Agricultural policy, land intensification, environmental impact assessment.

INTRODUCTION

Agricultural intensification relies on technical and chemical inputs to maximize crop yield rates, optimizing productive output per hectare (Jeliazkov et al., 2016, Rusch et al., 2016). Agricultural intensity is measured by 'Total Factor Productivity' (TFP), a function of proportional output gains and increased inputs. From the 1950's to 1980's, the UK's TFP rose significantly which implies increasing crop yields (Burgess and Morris 2009). From the 1990's onwards, TFP has remained rather static, since increases in marginal output where relatively small (Levers et al., 2016). This does not imply that agricultural practices have become significantly less input-intensive, but rather that

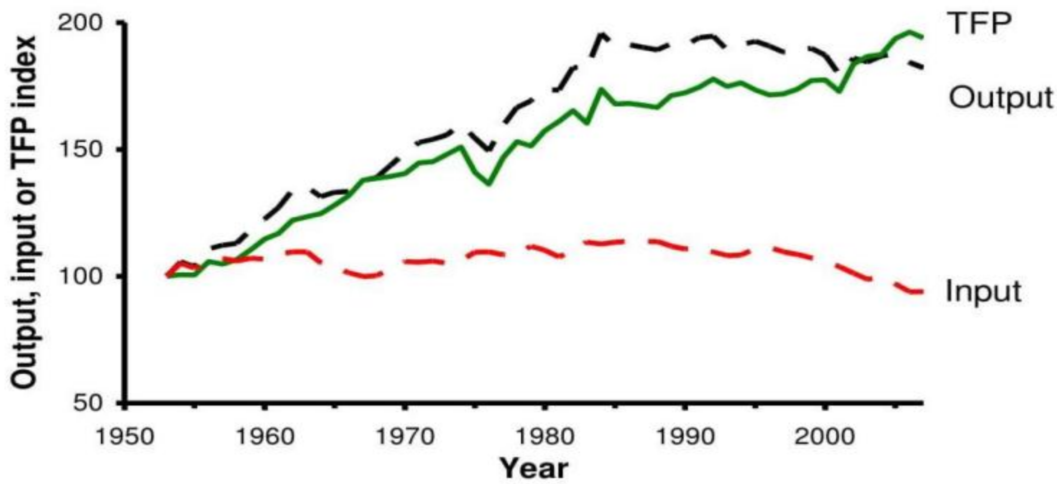

Figure 1: Taken from Burgess and Morris 2009. UK agriculture levels of inputs index, output index and Total Factor productivity index as a factor of time from 1953 to 2007.

Table 1: taken from Lang, 2004 in (Burgess and Morris 2009). Yields (t ha-1) of winter wheat, winter barley and Oilseed Rape in Eastern Counties of U.K. A comparison of the most profitable farms (top 25%) to the mean farm harvest.

Crop	**Wheat**		**Barley**		**Oilseed rape**	
Year	1989 -1995	1996 -2004	1989 -1995	1996 -2004	1989 -1995	1996 -2004
Top 25%	8.8	9.2	7.0	7.0	3.6	4.1
Mean	7.8	8.3	6.2	6.3	3.0	3.4

productivity is increasing at slower rates reflecting possible biophysical limits (Levers et al., 2016). Despite small decline in recent input values, environmental systems remain sensitive to intensification practices (Burgess and Morris 2009), Figure 1.

This is exemplified by wheat yields, which have displayed positive linear growth with decreasing yield rates. Growth of wheat yields began in the 1950's, primarily attributed to new crop strains and expansion of land dedicated to harvest (Burgess and Morris 2009). From the 1990's to the present, wheat yields have experienced static growth. Table 1 (Lang 2004) compares yield rates per hectare of three different common crops in the UK, expressing marginal increases over two periods. From 1989-2004, Wheat, Barley and Oil Seed Rape yields have increased on average around 6.4%, 1.6%, and 13.3%. Interestingly, the most profitable farms – top 25%- for Wheat and Barley have experienced less than average growth rates at 4.5% and 0% respectively. Overall, recent yield rate growth has been marginal in comparison to the significant boom in agriculture from the 1950's to 1970's (Burgess and Morris 2009).

Since agricultural intensification is a multivariant process, it is extremely difficult to disentangle individual components affecting the local biodiversity and environmental functions (Chamberlain et al., 2000). The following analysis focuses on environmental consequences from artificial pesticides and fertilizers, as well as the management of hedgerows under agricultural intensification practices in the UK. It must be noted that analysis of individual intensification factors is hence with scientific uncertainty, as factors inherently interplay once introduced in the environment. The extent to which policies have been successful, focuses on the spatiality of policy uptake and the effects on environmental systems. The key question this paper seeks to better understand, is how social factors have influenced the spatiality of agricultural intensification and policy.

METHODOLOGY

Timing: The choice to limit the time period from the 1970's to present is because this includes two distinct periods of UK agricultural intensification and policy. From the 1970's to 1980's, the UK's environmental and economic policy regime promoted practices of agricultural intensification. Following the declines in global food prices and growing public environmentalism, the 1990's represented a transitional period toward sustainable intensification and conversationalist policies. Hence from the 1990's to the present, the UK government has prioritized stricter environmental regulations which in turn has limited intensification practices at the farm level. Recent agricultural practices are compared to the earlier period of limited environmental policy.

Publication Status: No working papers or preliminary data was used in this review, to ensure the quality and reproducibility of results.

Location of Research: UK and EU areas were considered, to compare relationships between distinct regulatory regimes and environmental consequences.

Databases and Key Words: (a) The scientific literature assessed was collected through Elsevier's Science-Direct database, limiting the time period of research from 1970 to the present. Key-words searched for were: fertilizers, pesticides and hedgerow management. Quantitative research on the environmental effects after implementation of specific policy interventions was limited, highlighting gaps in the state of scientific knowledge over this issue. (b) Policy-related articles and reports were collected through Google Scholar engine and official UK government and EU agency websites. Key words for searched for were: environmental policy, economic policy, and agricultural policy. The year of policies analysed had effectual implementation during 1970's to 2000's. Current legislative movements were not considered. A drawback from using policy related articles and reports for environmental impact assessment is that data is mostly qualitative. The net results of policy implementation are biased toward discursive analysis as scientific data is incomplete.

Potential Biases: It is acknowledged that this article is biased toward a narrative review, as systemic analysis is limited by the state of scientific knowledge on recent policies' long-run effects on the environment.

RESULTS

Pesticides' knock-on effects for non-target species

Artificial pesticides were heavily subsidised from the 1970's to 1980's, in order to boost crop yields (Angus et al., 2009). Even after subsidies were disbanded in the 1990's due to agricultural surplus, cheaper pesticide prices incentivized the normalization of use (Levers et al., 2016). Consequently, pesticides are now "locked-in" factors since continued use has led to hyper-resistant strains, requiring more frequent application and higher lethal dose rates (Heap 2014). This is especially concerning, since pesticides have knock-on effects for non-target species through alternate and indirect pathways.

Farmland bird population are declining dramatically in the EU, due to bioaccumulation of pesticides in their systems (Jeliazkov et al., 2016). Particularly in the UK, skylarks and grey partridges have been found to be significantly affected by pesticides, treated as an independent variable to fertilizers and crop rotation. Results from random resampling protocols, found no significant deviation for pesticides as the explanatory variable for population declines (Mckenzie et al., 2011) The interaction term between pesticides and fertilizers was negligible, holding the validity of the claims (Mckenzie et al., 2011), Figure 2.

Pesticides were also found to affect ground-level communities which are critical for nutrient cycling, and hence soil fertility (Rusch et al., 2016). Furthermore, pesticides have significantly impaired the efficiency of natural pest control, creating pressures for enemy species (Rusch et al., 2016). Similarly, pesticides have affected pollinating insects, bees especially, resulting in reduced pollination potential (Hannon and Sisk 2009). These impacts seem to be amplified by alternate stresses relating to depletion of nesting sites and food sources (Holland 2004). This is relevant to mechanized tillage processes and poor management of hedgerows (Jeliazkov et al., 2016; Hannon and Sisk 2009). While McKenzie et al., 2011 suggest that pesticides have insignificant interaction with alternate factors of intensification, alternate data argues otherwise. The complexities of environmental systems generally favour the argument that consequences of continued pesticide use have interwoven with alternate factors of agricultural intensification (Wretenberg et al.,2009)

In response to these issues, recent UK policy is turning toward greater regulation of pesticides. Under the EU Directive, the UK has voluntarily banned many common pesticides from domestic market (Hillocks 2012). It has also adopted 'National Action Plans' for continued reductions of pesticides use by enforcing integrated pest management (Hillocks 2012). Integrated pest management (IPM) relies on traditional farming methods to maintain healthy populations of enemy species which naturally combat pests (Rusch et al., 2016). This can be achieved by increasing heterogeneity of fields which providing better habitats for enemy species and hence a large species richness/population of predatory taxa (Rusch et al., 2016).

However, there have been difficulties in reducing pesticide use and incentivizing IPM in large-scale farms as it requires significant changes in production models, and hence increased costs. This explains why the majority of UK farms voluntarily operating under environmental directives are small-scale and organic (Hodgson et al., 2005), highlighting the economic factors influencing policy uptake. National Action Plans seem to have localized success, yet limited possibilities for widespread domestic efficiency due to the inadequacy of economic incentives.

Alternately, genetic modification has led to new crop strains with built microbial pest resistance, like Bt Corn, which are increasingly cost-competitive with non-GM crop strains (Bates et al., 2005). Under current EU regulation, however, all forms of GM crops are banned. Similarly, the UK has pledged to maintain this regulation in Brexit trade negotiations (Hope 2017). Due to these overarching policy

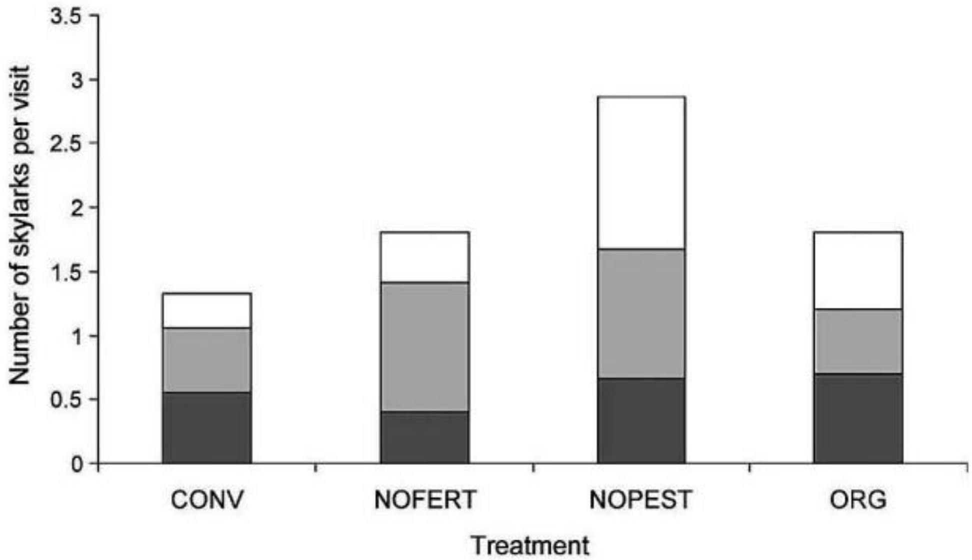

Figure 2: Figure taken from Mckenzie et al 2011 - Frequency of Skylark Occurrence in 50 randomly selected plots, with different treatments each given equal weight (Conventional, no fertilizers, no pesticides, and organic). Year 1 in the bottom of the stacked bar, Year 3 at the top. Pesticides applications significantly affected Skylark presence ($z= -2.92$, d.f. = -1, $p< 0.005$)

contexts, environmental issues from artificial pesticides will continue as there is no large-scale solutions proposed.

Nitrate fertilizers: eutrophication, deposition, and acidification

Environmental consequences from nitrogen fertilizers relate to eutrophication, deposition and acidification. Nitrate-rich run off has led to significant eutrophication of local creeks, affecting hedge bank flora (Theaker et al., 1995). This occurs as accumulation of nitrate concentrations in water increases the presence of weeds, which in turn reduces woody-plant species productivity (Theaker et al., 1995). Even in isolated plots, hedgerows were affected by atmospheric deposition of nitrogen (Staley et al., 2013). Similarly, heathland and grassland flora were observed to have reduced species' richness due to atmospheric deposition, resulting in widespread biodiversity loss (Maskell et al., 2010). Soil acidification occurs when ammonium-based fertilisers react with ground-water, resulting in increasing acidic soil conditions which can also affect floristic communities (Ostle et al., 2009). While these environmental effects are observed directly in primary producer populations, there are indirect effects on higher trophic levels via biological cascades (Maskell et al., 2010). This explains higher level biodiversity losses from associated reductions in primary food sources and habitat complexity (Ostle et al., 2009).

Under the European Nitrate Directive in 1991, nitrate fertilizer rates have declined by 10% (Levers et al., 2016). Furthermore, the UK has signed the UNECE Gothenberg Protocol, aiming to reduce ammonia emissions to 297,000 tonnes by 2010, which represents a 12% reduction from 2004 levels (Stoate et al., 2009). The UK government has also inflated synthetic fertilizer prices by over 270% to disincentivize further use (Angus et al., 2009). While these policies have been effective in reducing the level of fertilizer use, they have been relatively unsuccessful in targeting continued environmental problems. This is observable by similar scales of environmental issues in the UK and EU, despite different regulatory regimes (Levers et al., 2016). There is an evident difficulty in isolating effects by changes in individual components of intensification. While nitrogen application levels are decreasing in the UK dramatically, there may be alternate agricultural pressures which offset these improvements. Even when policy uptake is spatially uniform and successful in reducing absolute fertilizer levels, it is inadequate for addressing local environmental conditions. Complementary environmental regulations are necessary beyond price adjustments and supply-side strategies.

This has led the UK government to reconceptualize regulations, pushing complementary 'sustainable intensification' strategies through investments in new technologies (DBIS and DEFRA 2013). Companies like Syngenta have collaborated with the UK government to research and develop new fertilizers with lower environmental risks (DBIS and DEFRA 2013). However, like with any new technology, there is a limited understanding of potential long-term effects, since analysis is confined to experimental conditions. Therefore, organic farming may be a more viable alternative. It utilizes naturally sourced fertilizers, like compost-waste and dung, complemented by traditional crop rotations to increase soil

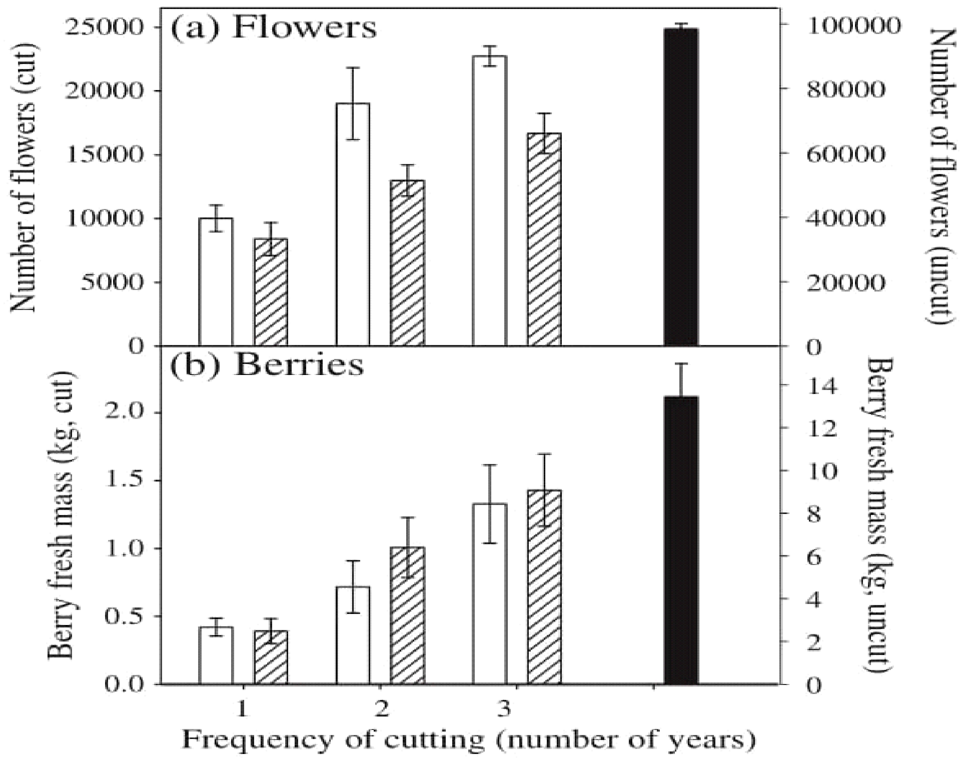

Figure 3: Taken from Staley et al 2013. Cumulative (a) number of flowers and (b) fresh mass (kg) of berries per m of hedgerow length over 5 years (mean ± SE) on plots cut annually, biennially or every 3 years in Autumn = Winter = compared with plots which were uncut =

fertility (Norton et al., 2009). Still, the application of organic farming methods is difficult to conceptualize over large-scale and commercialized plots. Given these technical limitations, environmental issues arising from artificial fertilizer use remain a problem in the UK as there are spatial conditions not adequately addressed in current policy.

Destruction and Poor Management of Hedgerows

Hedgerows presence in agricultural landscapes is critically important, as it not only provides shelter and food, but also environmental services. Hedgerows are critical refuges for wildlife in intensely managed landscapes, connecting fragmented plots and acting as 'country-side' corridors for species movement (Davies and Pullin 2007). It can provide important food sources and nesting sites for overwintering mammals, invertebrates and birds (Staley et al., 2011). Additionally, its floristic diversity attracts pollinating species, particularly bees, which later provide ecosystem services by pollinating nearby-fields (Hannon and Sisk 2009). Hedgerows may also prevent soil erosion, by reducing harsh winds over bare fields (Staley et al., 2013). Lastly, hedgerows sustain a healthy predator-species' population which delivers natural pest control (Rusch et al., 2016; Ramsden et al., 2015). Hence, the conservation of hedgerows has extremely high environmental value.

Despite the recognized importance of hedgerow conservation, their "health" remains at risk. Traditionally, hedgerow management included manual trimmings every 20-40 years which encouraged new shoots to grow (Staley et al., 2013). Over the last 70 years, however, management has become more intensive and mechanized (Croxton et al., 2004). It is now common practice to use mechanised flailing with annual frequency, resulting in the disappearance of 16 perennial woody species (Hill et al., 2004). This has reduced the refuge potential and floristic diversity of hedgerows, as they are increasingly composed of young and herbaceous plant species (Staley et al., 2013). Furthermore, the timing of mechanized trimming in autumn months decreased biomass of winter berries and spring flowers by 83% and 75% respectively (Staley et al., 2011) This limits hedgerows' food sources for overwintering species, as well as potential flower nectar for pollinating insects (Staley et al., 2011) Though direct removal of hedgerows is prohibited in the EU, over 8,000 km of hedgerows are annually lost in the UK due to poor management (Staley et al., 2011), Figure 3.

Political and management regimes have recently begun to address these 'vanishing hedgerows'. In 1992, the UK government implemented an Agri-Environment scheme (AES) which incentivizes conservation through payments for ecosystem services of "set-aside" agricultural lands (Hodgson et al., 2005). Currently, 41% of hedgerows are managed under AES regulations as this is a purely optional scheme (Staley et al., 2011). However, AES options allow for bi-annual cutting which has similar effects on hedgerows as intensive management. It is suggested AES options should opt for cutting regimes over more than three years, as this could increase biomass by 40% over current levels (Staley et al., 2011). This can be complementary to transitions toward organic farming which takes a more traditional approach to hedgerow management (Rusch et al., 2016). Infrequent manual trimming under organic methods has significantly improved species richness and populations in hedgerows (Norton et al., 2009).

However, the AES' effectiveness is questionable due to geographic clustering of conserved hedgerows over lowland areas, typically abandoned due to poor fertility (Hodgson et al., 2005). It is uncertain whether relatively lower extinction rates in lowlands are due to preserved hedgerows or merely land abandonment (Hodgson et al., 2005) Furthermore, environmental improvements in lowland can potentially be offset by vanishing hedgerows and agricultural intensification in upland areas (Hodgson et al., 2005). For environmental concerns to be adequately and uniformly addressed, there needs to be more comprehensive regulations targeting geographic demarcations in policy uptake. For AES to provide adequate economic incentives, a dual-payment scheme should be enacted which offers higher pay-out rates to highland regions with greater profit losses from voluntary conservation.

Conclusion

The UK's economic and environmental policies have changed drastically since the 1970's, highlighting transitions toward environmental consciousness in public organizations. This transition has transformed agricultural regulations, which now recognize the damaging environmental effects of intensification. There has been an evident push for sustainable farming practices, through monetary incentives via direct payments for ecosystem services, inflation of input prices, and subsidized investments for agricultural research. However, while these policies have been enacted on the national level, there seems to be a trend in localized successes. This raises questions of the longevity of these policies to address environmental issues at their core. The spatial clustering of voluntary conservation in organic, small-scale, or lowland farms has not been adequate to offset legacies of environmental damage. In order to incentivise policy and regulatory uptake over the entire space, it is necessary to reconceptualize how farmers react to policy measures. Despite growing public awareness and environmental consciousness, farmers still prioritize positive profits. A challenge for agricultural policy is that it must consider the underlying economic driving factors. Until sustainable farming becomes cost-comparable to modern efficiency through intensification, it seems unlikely that large-scale farms will voluntarily agree to stringent environmental conservation schemes.

Conflict of interests

The author declare that there is no conflicting interests

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