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Agronomic decision making in an uncertain climate

Climate Change: Getting the Policy Right

By DR SEAN RICKARD

Sean Rickard Ltd, Independent Economic Analysis, Milton Keynes, UK
Author Email: sean@seanrickardltd.co.uk

Summary

Global demand for food is projected to rise by at least 70 per cent over the next 35 years yet agriculture's ability to meet this demand is threatened by a number of production challenges. Rising prices for fossil fuels and minerals, insufficient freshwater and climate change form a 'trinity of threats' that if not successfully countered will result in the persistence of high and volatile food prices, increasing malnutrition and the greater likelihood of famines. This paper builds on a potential solution; namely, sustainable intensification that has attracted support from a wide cross-section of scientists and technologists. It focusses on two research questions: firstly, to what extent is sustainable intensification a capital-led intensification; and secondly, within the EU, what market-orientated policy reforms are needed to bring about a more capital intensive farming industry. The paper concludes that the phasing out of direct payments would speed structural change, concentrating production on larger scale farms that are in a stronger position to invest in capital-intensive sustainable intensification.

Key words: Sustainable intensification, natural resource productivity, drastic innovation, capital intensity, precision agriculture, economies of scale, common agricultural policy

Introduction

A scientific consensus has developed that two of the most important issues of the 21st century are climate change and food security (IPCC, 2014). Many farming practices in both developed and developing nations make excessive demands on natural capital; indeed, agriculture is a major contributor to climate change, responsible for around 10–12 per cent of greenhouse gas (GHG) emissions, excluding the impact of deforestation (*op cit*.). These demands must be set against the step-change in world agricultural prices to higher and more volatile levels since 2006 which is evidence that the gap between the world's demand and supply of food has widened. The contention underlying this paper is that the production shortfall inherent in global agriculture shifting from supply push to demand pull is likely to continue widening in the absence of drastic change. This paper argues that the change must include a substantial increase in the supply of food if it is to be affordable for all. However, agriculture's ability to achieve this objective is threatened by a number of production challenges; indeed, attempting to produce more food through a 'business as usual' approach is not an option. At a global level, rising prices for fossil fuels and minerals, insufficient freshwater and climate change form a trinity of threats that if not successfully countered will result in the persistence of high and volatile food prices, increasing malnutrition and more frequent famines.

Focusing on this ‘trinity of threats’ a successful policy response would involve action not only on the supply side but also on demand. This paper is primarily concerned with the supply side and more specifically, the extent to which European Union (EU) agricultural policy, i.e. the Common Agricultural Policy (CAP) delivers production systems that are capable of production growth while reducing demand for the natural resources used in production and decreasing harmful emissions of GHGs and other pollutants: in essence, is the CAP capable of delivering sustainable intensification. This is not to devalue the contribution that reducing household food waste and changing diets could make to lessening both demand and GHG emissions; rather, it takes the position that lifestyles and diets, rich in meat and dairy products, that are typical of developed countries will not alter drastically and will increasingly be taken up by developing countries.

This article focus on two research questions: firstly, to what extent is sustainable intensification a capital-led intensification; and secondly, what market-orientated CAP reforms are needed to bring about sustainable intensification. What follows is divide into three sections. The first argues that sustainable intensification is the appropriate objective for EU agricultural policy. The second explains why capital intensification at the farm level is necessary to deliver sustainable intensification and the third section outlines a policy framework that is most likely to achieve this objective.

Sustainable Intensification

World prices for agricultural commodities have risen sharply to historic highs and become more volatile since 2006: the outcome of underlying trends in supply and demand that began in the 1990s together with the impact of weather induced short-term shocks to global supply. This ‘new era’ is illustrated in Figure 1 for cereals and a weighted average of five key commodity groups including meat and dairy products. The ‘new era’ can be attributed to a rising global population and in particular development. In developing countries economic growth has been strong since the early 1990s; indeed, the exceptional growth in China and India, with nearly 40 percent of the world’s population, has provided a powerful and sustained stimulus to the demand for agricultural products as rising incomes are reflected in diets that include more meat and dairy products.

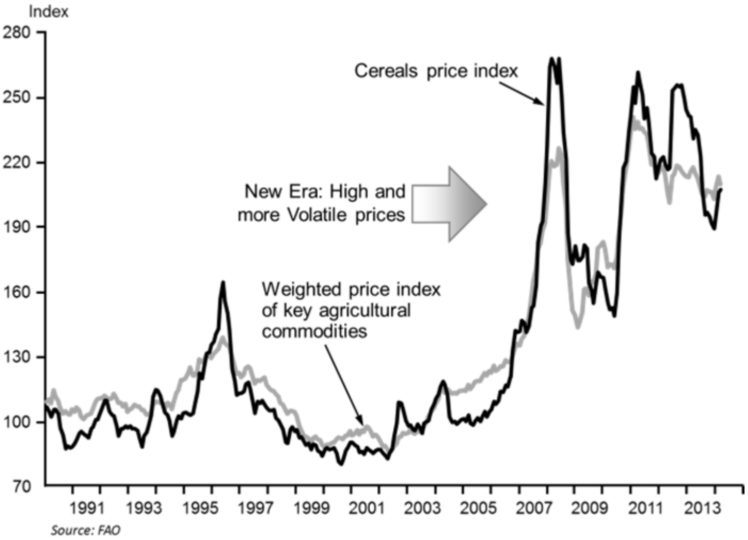

Fig. 1. FAO Monthly Price Index for World Agricultural Prices.

On the supply side a number of adverse trends are contributing to a slowdown in productivity growth: see Fig. 2. These challenges include: a gradual decline in the world’s arable area as land is converted to non-agricultural uses; substantial rises in the prices of key production inputs such as energy and minerals; the continued degradation of freshwater sources as rivers and aquifers dry-up; and the growing incidence of extreme weather on regional production. To a greater or lesser extent these trends are contributing to a slowing rate of increase in grain yields – indeed in Europe cereal yields appear to have plateaued.

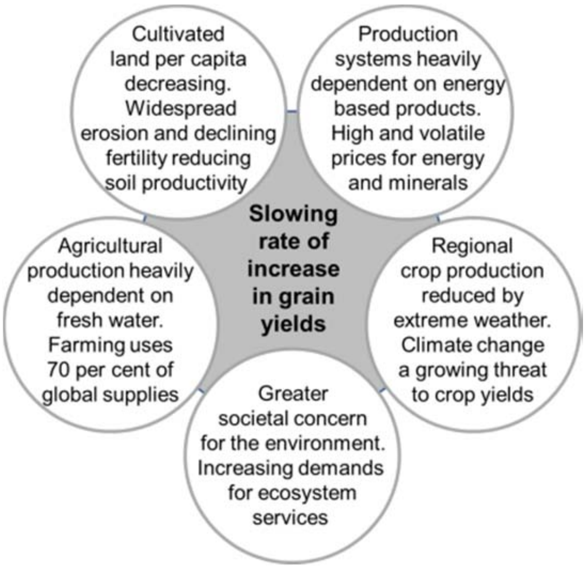

Fig. 2. The Agricultural Supply Challenges.

The slowdown in the growth of grain production should be a matter of serious concern; the more so as almost 40 per cent of the world's grain is fed to farm animals. The only practical response to slowing yield growth and the challenges summarised in Fig. 2 is sustainable intensification a technology that … *improves production without adverse ecological consequences* ... [is] ... *less vulnerable to shocks and stresses* … [and contributes] … *to the delivery and maintenance of a range of valued public goods, such as clean water* [and] *carbon sequestration* (Royal Society, 2009, 7 pp.). Garnett & Godfray (2012) have argued that sustainable intensification denotes an objective and is weakened by its failure to align with a specific production system. However, this criticism is itself weakened if it is accepted that sustainable intensification must involve a significant increase in production over the next 30 years if the world is to achieve a position of food security (see Royal Society, *op cit*., Foresight, 2011). Academic studies suggests output will need to rise 70–100 per cent by 2050 (see for example, FAO, 2009; Nelson *et al*., 2010) on the assumption that there will be no radical change in dietary preferences in developed countries and developing nations will continue along a trajectory of rising per capita consumption of meat and dairy products towards European if not North American levels.

This rules out, certainly from a European perspective, a general switch to low-input-low-output systems such as organic farming. Systems that rely on ecological processes rather than the use of synthetic inputs make lower demands on natural resources and on this basis can claim to be sustainable – though carbon based flame weeding raises a question mark – but a comprehensive analysis of available data by Seufert *et al*. (2012) concluded that:

….. overall, organic yields are typically lower than conventional yields. But these yield differences are highly contextual, depending on system and site characteristics, and range from 5 per cent lower organic yields (rain-fed legumes and perennials on weak-acidic to weak-alkaline soils), 13 per cent lower yields (when best organic practices are used), to 34 per cent lower yields (when the conventional and organic systems are most comparable), (*op cit*, pp. 229).

For systems that eschew synthetic inputs the impact of lower yields on production is compounded by the need to rotate arable land and grass leys. In the absence of a drastic decline in the consumption of meat and dairy products this implies the need for more arable land which in turn would necessitate widespread deforestation and biodiversity loss, thereby undermining the claimed environmental and climate change benefits of such systems.

There are many, including the organic movement, who question the need to increase food production arguing instead that the problem is one of intensive livestock production. It is indisputable that a reduction in the consumption of meat and dairy products in developed nations, accompanied by a scaling back in the aspirations of developing nations would reduce the consumption of grains and consequently future agricultural demands on natural resources as well as moderating GHG emissions (see for example, Stehfest *et al*., 2009). However, there is little agreement as to the extent of the reduction in consumption of these products let alone the mechanism. It is, I believe, more pragmatic to assume that global demand will continue rising and sustainable intensification will be required to simultaneously deliver a substantial rise in output and natural resource productivity (NRP) i.e. output growth not involving, or severely limiting, increases in the volumes and quality of natural resources used in its production.

Another approach argues that food waste is the issue and its reduction within the supply chain and households would alleviate the need to produce more. While waste is incompatible with economic efficiency a major problem with this approach is the lack firm evidence from which to assess the extent of food waste globally. Estimates range from 10 to 40 per cent of global food production but on closer examination, these estimates all link back to the same limited primary datasets, where much of the published data relates to fieldwork undertaken in the 1970s and 1980s. Recent reviewers of these data claim there is a tendency to over-state losses in developing countries though there is strong evidence of an increase in household waste over the past several decades, particularly in developed nations (Parfit *et al*., 2010). Many initiatives are now underway in rich countries to reduce the proportion of household food waste but even if such waste was reduced to zero it could make only a relatively small contribution to the global demand and supply imbalance and from this perspective the priority must be agricultural production.

Capital Intensive Sustainable Intensification?

As defined above sustainable intensification has two objectives: the economic benefit of a substantial increase in both arable and livestock production; and the ecological necessity of reducing the industry's demands on the world's natural resources – particularly non-renewable resources – and its impact on the climate. By definition NRP is defined here as:

$$\text{NRP} = \frac{\text{Units of Agricultural Output}}{\text{Units of Natural Resources and Emissions}}$$

where NRP is the growth of output not explained by changes in the volumes and quality of natural resource inputs including emissions and for sustainable intensification the change in agricultural output must be positive. There appears little attempt to isolate NRP in the economics literature where the main focus is total factor productivity (TFP) – in this case the denominator includes human and fixed capital as well as natural resources – whose growth is viewed as a weighting of technical efficiency and technological advance (see for example Fuglie (2008); Leetmaa *et al.* (2004)). Decomposed on this basis the results mostly show technological advance – i.e. the application of new knowledge in the areas of science, engineering and management – as the major determinant of TFP growth (Coelli & Prasada Rao, 2005). Beddington (2009) argues that the scope, mechanisms and technologies to increase agriculture's output and NRP while reducing GHG emissions are relatively unexplored and significant gains could be delivered through a combination of technological advances and farming practices. Fig. 3 sets out the three main elements of NRP and provides a summary of the likely impact of technological advances and enhanced human capital, i.e. farmer capabilities.

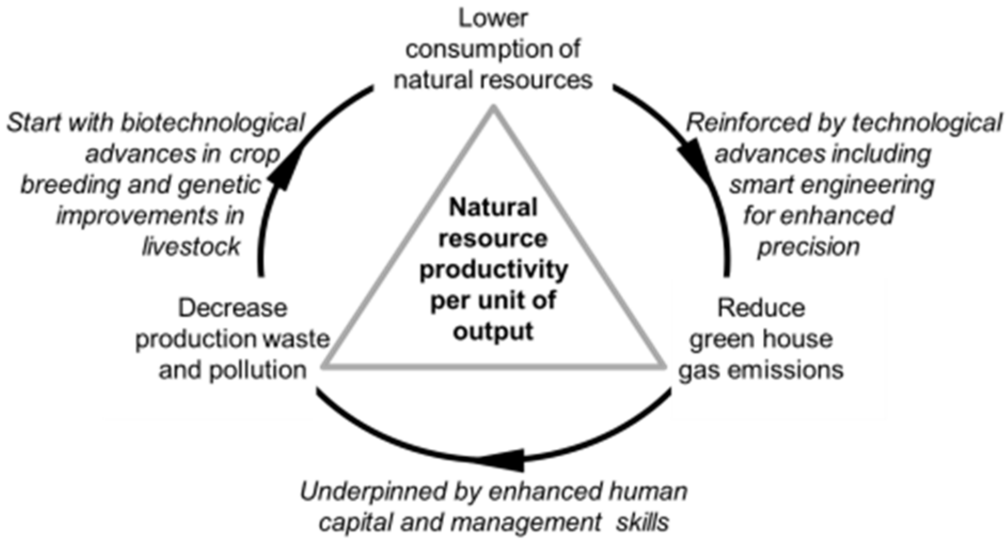

Fig. 3. Natural Resource Productivity.

By definition the new knowledge that drives technological advances cannot be articulated until it is discovered but it is possible to hypothesise that biotechnology and information technology are likely to be prominent in a concerted effort to achieve sustainable intensification. Biotechnological advances involving the cloning, transfer and manipulation of genes would appear to offer the prospect of raising the efficiency of nutrients and water in crops as well as stress tolerance and disease resistance. Similarly genetic improvements are likely to be a major source of advances in livestock nutrition, immunology and feed efficiency. However, the benefits of new knowledge will only be realised when adopted at the farm level and this will require not only enhance human capital and management but also a suite of mechanised developments such as no-till systems for soil carbon capture (Robertson *et al*., 2000) and the widespread adoption of precision technologies to ensure that the requisite resources for crop growth and protection are met without deficiency or excess at each point in time during the growing season (Cassman, 1999).

Precision technologies, essentially the fusing of agricultural engineering and information technology – knowledge engineering – hold the prospect of a major contribution to sustainable intensification through capital intensity at the farm level. Developments in areas such as scanning and sensing will allow better selection, management and control of crops and livestock. Yield monitors, variable-rate technology, GPS mapping, auto-steering can reduce resource demands by adjusting usage according to variations in soil properties, crop requirements, pests and disease. Even robotic systems can reduce natural resource demands and emissions as they lessen incidents of human error and waste. The importance of advances in knowledge engineering is illustrated by estimates that about 50 per cent of the effectiveness of crop protection is dependent on factors such as the timing and the precision of application (Robinson, 2008).

A technological revolution to deliver sustainable intensification, involving precision technologies, would necessitate two parallel developments; a step change in R&D expenditure to achieve a cluster of drastic innovations; and the necessary structural change to higher levels of capital intensity at the farm level to efficiently utilise these innovations. In his *Capitalism, Socialism and Democracy*, Schumpeter (1975) presented economic progress as an evolutionary, cyclical process which is triggered by a single or cluster of drastic innovations followed by a massive diffusion of smaller, incremental innovations that exploit directly or indirectly the profit potential inherent in the initial radical change. Diffusion drives far reaching industrial transformation involving new products and processes that: *incessantly revolutionizes the economic structure from within, incessantly destroying the old one, incessantly creating a new one. This process of Creative Destruction is the essential fact about capitalism* (*op cit*. p. 83).

Drastic innovations tend to take place in bursts for example as manifested in the 1960s 'green revolution' where a cluster of drastic innovations resulted in a prolonged increase in productivity based on crop breeding, chemical and engineering technologies. The bulk of the contributions to agricultural productivity over the past 60 years – cereal yields in Europe more than trebled between 1960 and 2000 – can be traced back to innovations emerging from the green revolution (Evenson & Gollin, 2003). Leading scientists (Royal Society, *op cit*, Beddington, *op cit*, Cassman, *op cit*.) have expressed the belief that science and technology research has the potential to deliver a second green revolution focussed on the achievement of sustainable intensification. However, all these authorities draw attention to the fact that globally public spending on agricultural R&D has suffered an extended period of stagnation while private sector research has grown but its commercial orientation has placed the emphasis on cost reduction rather than yield increases (Pardey *et al*., 2006). To quote Beddington:

Science has contributed greatly in the past to finding solutions, and it can do so into the future if the investments are made. A new greener revolution can be built on the foundations of the first green revolution, but we will need to fully explore the range of science and technology opportunities at our disposal in the twenty-first century in order to overcome the greater constraints. This vital contribution from science will not happen by default (*op cit*. p. 68).

The intended longer term effect of sustainable intensification is shown schematically in Fig. 4. Starting at point A this represents the efficient outcome for a farm using the prevailing technology around the start of the 1990s when the prices of non-renewable resources were relatively low. Point B shows the position twenty years on where science and technology have brought about an increase in NRP as a result of an incremental technological advances in the prevailing technology but higher prices for non-renewable resources have reduced the consumption of natural resources e.g. fertilizers, causing (or contributing to) a plateauing in yield growth. Point C represents the outcome for organic production reflecting higher NRP but only at the cost of a significant reduction in output. Not shown in Fig. 4 is labour productivity which is much higher in conventional than organic farming and consequently point C also represents a higher per unit cost of production.

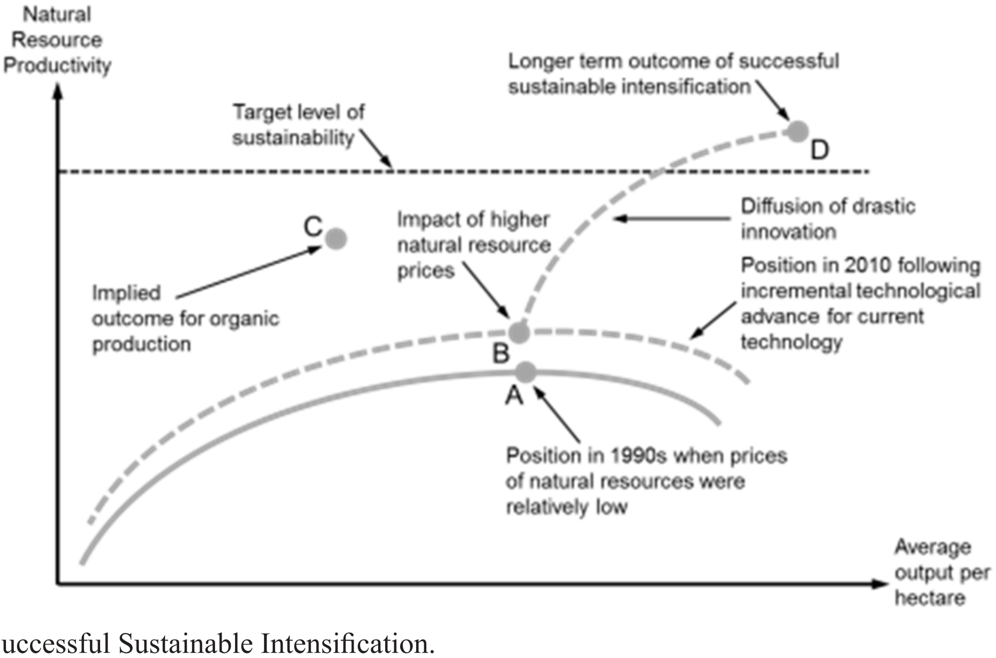

Fig. 4. Successful Sustainable Intensification.

The curve BD represents the diffusion of drastic innovation which renders the prevailing production technology uneconomic and is followed by a sequence of incremental advances. To the extent that the expectations of leading scientists for sustainable intensification are realised following drastic innovation (see for example Tilman *et al*., 2011; Beddington, *op cit*., Cassman, *op cit.* and Royal Society, *op cit.*) so there will be a corresponding direct and indirect impact on the mitigation of GHG emissions. Rising NRP results in direct mitigation per unit of output arising from the more efficient use of carbon based energy and farming practices such as no-till. Scope for indirect mitigation is created if the rise in NRP is sufficient to release large areas of land from agricultural production offering scope to use marginal lands and uplands to deliver ecosystem services such as woodlands and habitat conservation, recreation as well as carbon sequestration (Burgess & Morris, 2009).

The CAP and Sustainable Intensification

The foregoing has argued that sustainable intensification offers a potential solution to the challenges facing agriculture but to the extent that it is based on knowledge engineering and increasing capital intensity so progress depends on expensive investment at the farm level (Dumler, 2000; Schimmelpfennig & Ebel, 2011). It follows that only farms capable of generating sufficient profits to fund such investments would be able to engage fully in capital intensive sustainable intensification and this implies that larger scale farms, in a position to benefit from economies of scale, have an inherent advantage. Many studies have demonstrated that significant economies of scale exist in all sectors of agriculture. An OECD (2011) review of current knowledge relating to the linkages between agricultural productivity growth, innovation and public policy observed that *…a general finding from these studies is that larger farms are better performers as they can achieve economies of scale and benefit from access to output and input markets* (*op cit*: 64). As observed above plant and machinery embodying knowledge engineering is expensive and therefore requires not only access to investment funds but also a larger volume of output over which to spread the cost. Larger scale farms, even those that have exhausted economies of scale and are operating at constant returns are likely to be generating profits (Rickard, 2000) that can be employed to fund fixed capital investments. Indeed, the diffusion of engineering based, technological advances has been accompanied by an increasing concentration of agricultural production on larger scale farms (Kislev & Peterson, 1996). Moreover there is some evidence that when a scale invariant advance, e.g. GM crops, is combined with scale enhanced advance, e.g. precision technology, farms gain an additional economy of scope (Fernandez-Cornejo *et al*., 2001; Roberts *et al*., 2006). The relationship between scale and a farm's ability to invest in capital intensive, sustainable technologies is illustrated in Fig. 5.

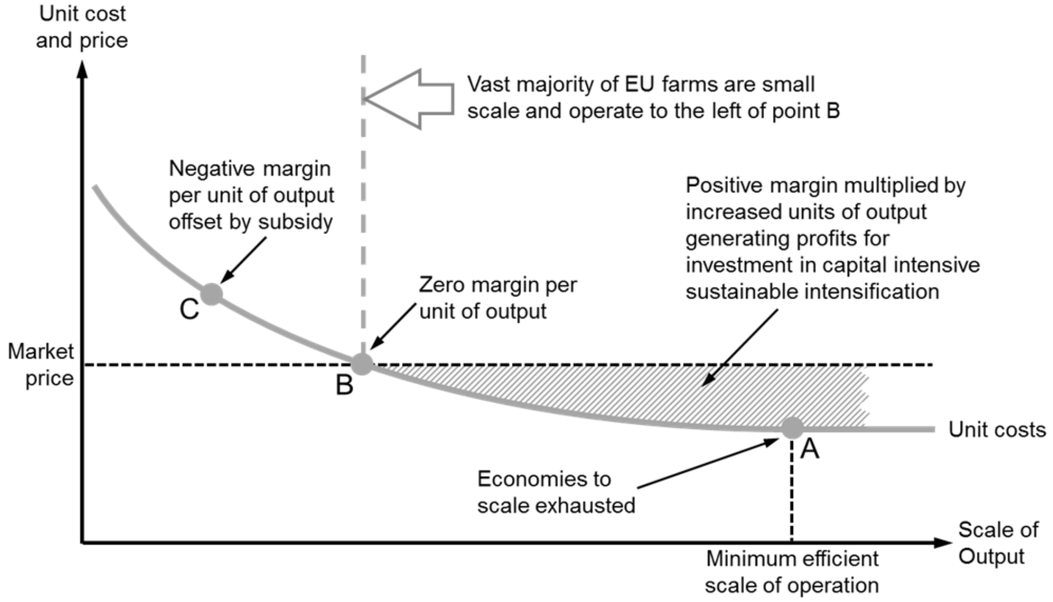

Fig. 5. Scale and Investment.

In Fig. 5 unit costs of production decline as scale increases but at point A economies of scale are exhausted and beyond this point increases in the scale of output are match by a proportional increase in costs. At the scale represented by point B net returns from farming operations are only sufficient for the farm to break-even. It follows that only farms operating at a scale in the vicinity of point A would be in a position to invest economically in capital intensive, sustainable intensification. Unfortunately, for the vast majority of EU farms their scale places them to the left of point B: they are represented by point C and are loss making but exit is delayed by the direct payments made to all farmers under the CAP. From this perspective direct payments can be interpreted as an offset for scale inefficiency and as such have proved unable to prevent a steady annual decline in farm numbers and a corresponding increase in the average size of farm. Most EU farms (70 per cent) have less than 5 hectares of agricultural land (Commission, 2013); only 3 per cent have more than a 100 hectares but these farms account for more than 50 per cent of the agricultural land (*op cit*). More significantly, these larger scale farms reveal superior productivity; the average value added per labour unit on the EU's largest farms is more than ten times the figure for the group of smallest farms (Commission, 2010). It follows that these larger farmers are in a much stronger position than their smaller counterparts to generate the investment funds required for capital intensive, sustainable production.

In principle the objectives of the CAP have become increasingly multifunctional embracing *inter alia*, sustainability and reduced GHG emissions, but multiple objectives are in conflict with the clear and coherent objectives necessary for efficient and effective policies (Tweeten, 1970) and not surprisingly the CAP largely fails to satisfy any of its objectives (Matthews, 2012). That said, in reality the political leadership of the EU views the social objectives of the CAP as *primus inter pares*. In October 2011 the European Commission published its proposals for yet another reform of the CAP and in an accompanying document (Commission, 2011) presented three future policy scenarios, one of which analysed the effect of progressively phasing out direct payments by 2020. This scenario was firmly rejected as it would … *lead to failure of many agricultural holdings and would put additional pressure on the viability of rural areas with higher unemployment and migration* (*op cit*. p. 72). This reveals the Commission as continuing to regard the CAP as primarily a social policy, a conclusion reinforced by its acknowledgement that the resulting restructuring following the phasing out of direct payments would not only lead to:

… *a more competitive and less diverse sector* ... [but also] .... *farms which will continue to be economically viable in the new environment will be larger, more open to innovation leading to cost optimisation, productivity growth and less labour-intensive* (*op cit*. pp. 72–73). The Commission further justifies its rejection of a policy to phase out direct payments by claiming that the larger scale farms emerging from the structural change would cause the … *likely intensification of production in fertile areas and the abandonment of production and land in more marginal regions* [with] *far reaching environmental consequences* (*op cit*, p. 75).

Drawing on the Commission's impact study (*op cit*.) the hypothesis advanced here is that the pace of restructuring would be faster in the CAP's direct farm payments were phased out. Direct payments, by allowing unprofitable, less efficient farms to remain in the sector are in conflict with the concept of economic sustainability: a necessary condition for ecological sustainability. Such farms do not generate a surplus to fund performance improving investment yet, in many cases their occupation of farm land necessarily limits the growth opportunities for more profitable, expansion-oriented farms and/or denies the ecosystem services that might be delivered on land taken out of agriculture. In short, the evidence suggests that agricultural TFP growth in the EU – and therefore very likely NRP growth – is being constrained by the existence of direct payments. Not only does their existence ensure that the CAP can never satisfactorily achieve its multifunctional objectives (Rickard, 2012), but also the existence of direct payments implies that a large number EU farms would be unable to fund capital intensive, sustainable intensification.

The evidence that smaller scale farms are at a disadvantage when it comes to investing in capital intensive technologies necessary for the delivery of sustainable intensification also implies that the take-up of technological advances necessary for the maintenance of the global ecosystem will be frustrated (Burgess & Morris, *op cit*.). The Commission's concern that a more productive industry would release land is addressed by Renwick *et al*. (2011) who analysed the effects of phasing out direct payments and concluded that:

… the analysis has highlighted that there are potential economic (efficiency) and environmental gains (lower overall greenhouse gas emissions, reduced nutrient surpluses, reduced erosion etc) to be had from wider reforms of agricultural and trade policy. In addition, there are potential environmental benefits arising from the process of abandonment itself (*op cit*: pp. 16–17).

Concluding Thoughts

The capital intensive approach to sustainable intensification outlined above is focused on developed nations, and the EU in particular, where labour is relatively expensive. This is not to imply that a plentiful supply of cheap labour would offer an alternative solution. Indeed, labour intensive, capital-deficient systems, typical of smallholder farming in under-developed countries, are neither productive nor sustainable (Reardon *et al*., 1999). Scale is critical to capital intensive production but it would not be fruitful to attempt to quantify appropriate levels whether in terms of turnover or area, the more so as the capabilities of the individual farmer are also highly relevant. But by phasing out direct payments the EU would significantly speed-up the rate of structural change bringing forward the concentration of production on larger scale farms. Studies show that larger scale farms not only generate larger profits but also are more receptive to change thereby offering a greater likelihood of higher levels of investment in capital intensive, sustainable intensification (OECD, *op cit*.). Also larger scale farms are in a stronger position than their smaller counterparts to attract and reward higher levels of human capital; an important consideration with the knowledge that the adoption of capital intensive, knowledge engineering demands higher levels of human capital (Huffman, 2001).

I have also identified the need for a step change in R&D expenditure to bring forth the drastic innovations necessary for sustainable intensification. One positive effect of a decision to phase out direct payments would be the scope to divert considerable funds to public sector agricultural R&D. Another positive effect would be the signal to public and private research centres that in future the European farming industry would be more capable of investing in capital intensive, knowledge based solutions. Finally, the phasing out of direct payments would create scope for better targeted and funded environmental and rural policies. Stand-alone environmental policies – to deliver carbon sequestration as well as ecosystem services – and rural economy policies would be freed to pursue objectives based on non-agricultural priorities. By ending the incorporation of environmental and rural policies into the CAP these policies could be better targeted to more efficiently meet national and regional objectives (Baldock *et al*., 2001).

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