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MODELLING AN AGROECOLOGICAL UK IN 2050 – FINDINGS FROM TYFA$_{REGIO}$

Xavier POUX (AScA-IDDRI), Michele SCHIAVO (IDDRI)

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Contact: Xavier.poux@iddri.org

ABSTRACT

FOREWORD

This document contributes to the Ten Years For Agroecology in Europe (TYFA) foresight exercise led by IDDRI and AScA, whose overall objective is to identify under which conditions a large scale agroecological transition could unfold in Europe. Following a first study released in 2018, showing the plausibility and the desirability of such a transition at an EU "grain" of analysis, IDDRI and AScA have worked in close cooperation with the Food, Farming and Countryside Commission and the Soil Association to specify the implications of such a scenario for the UK, with a view to contribute to the post-Brexit discussions on the UK Agricultural Policy. The present document presents the modelling work carried out in pursuing this objective. It is a DRAFT version of the full study, which be released in a final form by February 2021.

The study has been funded by the Esmée Fairbairn Foundation, which we want to thank. The Food, Farming & Countryside Commission have steered the study during the year 2020.

It has benefited from advice of an advisory group made up of the following experts:

- Professor David Barling, Director of the Centre for Agriculture, Food and Environmental Management, Hertfordshire University
- Professor Tim Benton, Research Director - Energy, Environment and Resources, Chatham House
- Dr Michelle Cain, Science and Policy Research Associate, UoO/Cranfield University
- Dr Janet Dwyer, Professor of Rural Policy, Director of CCRI - University of Gloucestershire
- Jyoti Fernandes, Campaigns and Policy Coordinator, Landworkers Alliance
- Dr Tom Finch, Conservation Scientist, RSPB
- Dr Tara Garnett, Food Climate Research Network Leader, University of Oxford
- Dr Laurence Graham Smith, Lecturer in Agroecology, RAU
- Chris Howe, Head of Food and Landscapes, WWF
- Professor Tom Macmillan, Research Director, FFCC/RAU
- Gareth Morgan, Head of Farming and Land Use Policy , Soil Association

This document is nonetheless the responsibility of its authors and does not engage the members of the advisory group nor expresses their view.

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1 BACKGROUND: EXPLORING THE AGROECOLOGY PATH

1.1 Agroecology vs. Intensification in the light of global and local challenges

As the rest of the world's food system, the UK one has to address a series of challenges dealing with the three dimensions of sustainability: economic, social and environment. Over the last decades, it has become clearer that environmental sustainability was not only a tradable dimension against the two others, but the fundamental basis for the future of all food systems, including ours.

In this perspective, it has also become clearer that the continuation of the current input-intensive farming paradigm could is not sustainable. Its impacts on climate, biodiversity, food quality, landscapes and soils have largely been documented at World, National and regional levels. Its success in terms of economic Gross Output, Food Industry employment and the provision of low-cost food are now to be considered against the wider impacts on the above mentioned aspects. Not only the "externalities" of current farming needs to be accounted in the domains of water quality, public health, biodiversity but they have to be questioned if they indeed are only "externalities". The following figure shows the development of wheat yield in the UK over the long period.

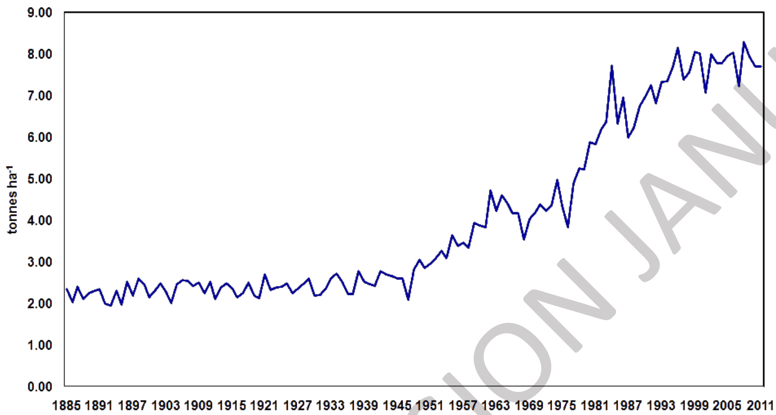

Figure 1: UK wheat yields 1885-2011 (source DEFRA)

The recent development shows both a plateau and increased variability over the last decade. Climate change is one key explaining factor, but dysfunctional agro-ecosystems – including the central soil component – should also be considered [réf]. And this is not only taking place in UK, but in all developed countries.

In this context, two paradigms are candidate for addressing the environmental and socio-economic challenges:

- The Intensification one, consisting in addressing the challenges by an efficient use of inputs allowing a maximal production on a limited amount of land. This expected high-yield performance allows "freeing" land for environmental use (e.g. woodland) or, alternatively, energy biomass production. Conceptually, this paradigm refers to a land-sparing strategy;
- The agroecology one, consisting in an absolute economy in the use of external synthetic inputs in order not only to limit the impacts outside the agriculture land, but to promote a genuine biodiversity-friendly farming within its boundaries. In the Western European context where current farming has been developing on high level of inputs, agroecology cannot hold the promise of high yields and thus, is strongly questioned.

In comparison with the promises of Intensification , agroecology looks like a tricky path to address all the many challenges, in particular with regards to the climate and the global food supply agenda and, to some extent, to the biodiversity one when considering the potential of Intensification to free land for wilderness by instance.

As a matter of fact, our proposition to further explore the agroecological path in the UK and European context is based on the identification of fundamental shortcomings of Intensification and the criticism of the "European countries must produce to feed the rest of the World". Starting by the latter and without investigating any further in this document, we refer to the Agrimonde Terra study[i] which has shown how the issue is not firmly established. Europe has not the potential to become a big export player in terms of global food security. However, the criticism of Intensification in and for Europe is outlined in the following points:

- While Intensification focuses on efficient use of inputs – fertilisers and pesticides – per ton produced, it does not address the absolute level of such inputs. The issue for fertilisers indeed is a matter of balance, but it is not the case for pesticides, where negative impacts can occur at very low absolute doses. The "efficient use" of pesticides, even measured in active dose per ton, may not be harmless for biodiversity, natural resources and potentially, health. The lack of explicit assessment of pesticides in Intensification is a major shortcoming.
- SI proposes a kind of trade-off between low-biodiversity inside agricultural land and high-biodiversity outside it. In the UK and more widely European context, this trade-off ignores (i) the fact that an irreplaceable bulk of biodiversity heritage stands inside some agricultural land, namely those of High Nature Value (ii) that intensive farming has impacts outside its boundaries, through pollution transfer towards freshwater, adjacent terrestrial ecosystems – sometimes remotely affected by aerial dispersion of fine particles – and marine ecosystems (eutrophication, pollution). In a country where landscapes and habitats of different kinds are closely intertwined, the spatial partition proposed by Intensification rises serious issues when considering its adjacent direct and indirect impacts.

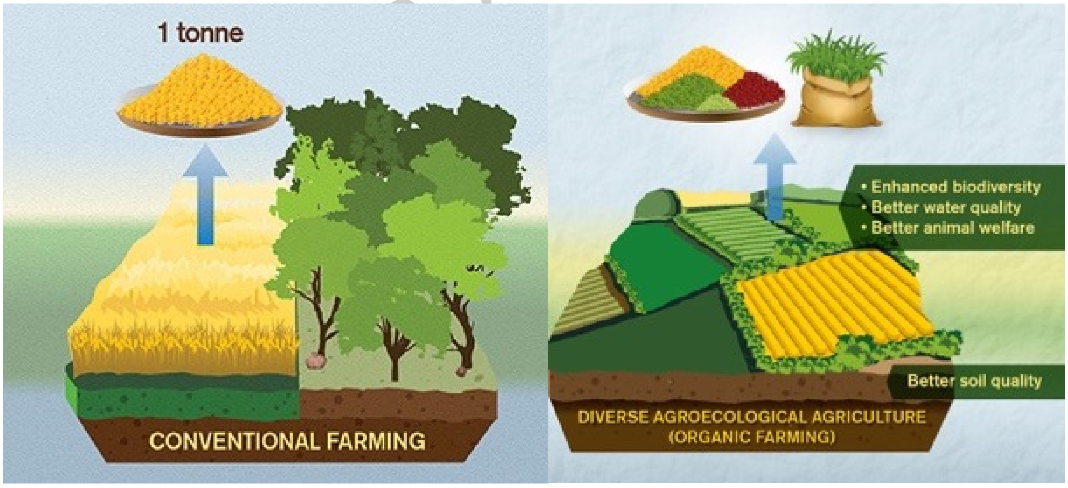

Figure 2: The conceptual frame of Intensification (left) leads to simplified landscapes assessed through Life Cycle Analysis focusing on their physical outputs and the efficiency of the inputs. The conceptual frame of agroecology leads to complex landscapes, providing diverse ecosystem services which assessment cannot only rely on LCA (source: Chalmer University) [email sent 25/11/20 for copyright]

However, despite such criticism in terms of biodiversity management, Intensification has two main assets on the environmental agenda, dealing with climate:

- The efficient use of inputs per ton makes it the perceived best candidate for GHG mitigation. One cow producing 10 tons of milk does not emit twice as much as two cows producing each 5 tons only.
- Freeing land allows the production of biomass for other purpose, including nature-based CO_2 removal and renewable energy.

It may appear there is a choice to make between climate mitigation and biodiversity. However, we propose another outlook on the promise of Intensification in terms of production. Intensification assumes that the potential for yield increase is high – as reflected in the set of assumptions used for the CCC scenario for the UK – that figure 1 strongly questions. The fact to mitigate emissions will not alter the short and medium term impacts on yields, all the more that the technical model supporting Intensification continues the fertility management and landscape configuration explaining the dysfunctionning of agro-ecosystem. In short, the structural factors potentially explaining the recent trend in yields are kept unchanged. This risk undermines the promise of Intensification and its delivers at the end. Biodiversity is not an externality, it is also a production factor based on fertility management and sustainable soil life.

Thus, there is a point in investigating and assessing the alternative proposed by agroecology.

1.2 Is agroecology agronomically and socio-economically sustainable in the UK?

Agroecology is increasingly being acknowledged as a promising way to address the environmental challenges. But yet, two questions emerge when envisaging its change of scale:

- What does it consist in the European context? This question arises in a context where most research in the field of agroecology have been conducted in tropical/developing countries, with strong social and political dimensions and specific environmental characteristics. Proposing an agroecological option for the UK implies to better specify what it consists in: is it a synonym of organic farming? Of High Nature Value Farming? Is it mainly a matter of small permaculture farms?
- Provided that it is clearly defined, and despite its potential environmental assets, while agroecology often means lower yields, is it productive enough to feed the UK population? Or, if national self-sufficiency is not a goal as such, would not agroecology lead to dangerous shores where most food should be imported? much beyond a safe operating zone. One might have in mind the criticism against organic farming on this ground: organic farming does not produce enough/ha and its generalisation would consume more land than we have.
- Agroecology stands on the use of organic fertilisers produced by herbivores, producing methane, a powerful greenhouse gas. Combined with low output characteristics, doesn't this simple fact dismiss agroecology? Can we afford such emissions?
- Even if agroecology is sufficiently productive to feed the UK population, does it leave space for the restoration of unfarmed ecosystems?

The production criticism of agroecology refers to its low-(imported) inputs approach. And indeed, in the UK context Figure 1 tells that yield has boomed in recent times, until the last decade (not included), and this is due to the use of high level on inputs. As already mentioned, agroecology does not pretend to hold a high yield promise. Its aim in terms of production is to keep it sustainable through time while preserving ecosystem integrity, starting with healthy soils. This care about sustainability entails a revision to a lowering of prospects of comparable yields, compared with present or SI. Lower, but safer yields could describe the approach. Healthier also if we think about the absence of residues, of richer Ω3 products and micro-nutrients content.

Let us clarify: agroecology is not a "back to the past" low yield farming for the sake of nostalgia. It is a scientific approach to production, considering ecosystem functioning in order to maximise nutrients flow mobilisation and life of precious auxiliaries: mycorrhizae, bacteria (and notably the precious azotobacter, fixing nitrogen from the air), insects, birds – all whose presence depends on a much reduced level of negative chemical inputs..

Let us also clarify another point: lower yields are indeed incompatible with the provision of the same level of food as we have today. If the assumption is keeping the amount of meat and dairy products eaten unchanged, there is no need to further investigate: agroecology – or organic farming - is not a credible option. The above mentioned studies concluding that organic farming is not productive enough have a major shortcoming: they keep the diet unchanged. However, we need to change our diet for climate and for our health. The good news is that the two go hand in hand and that it is already taking place.

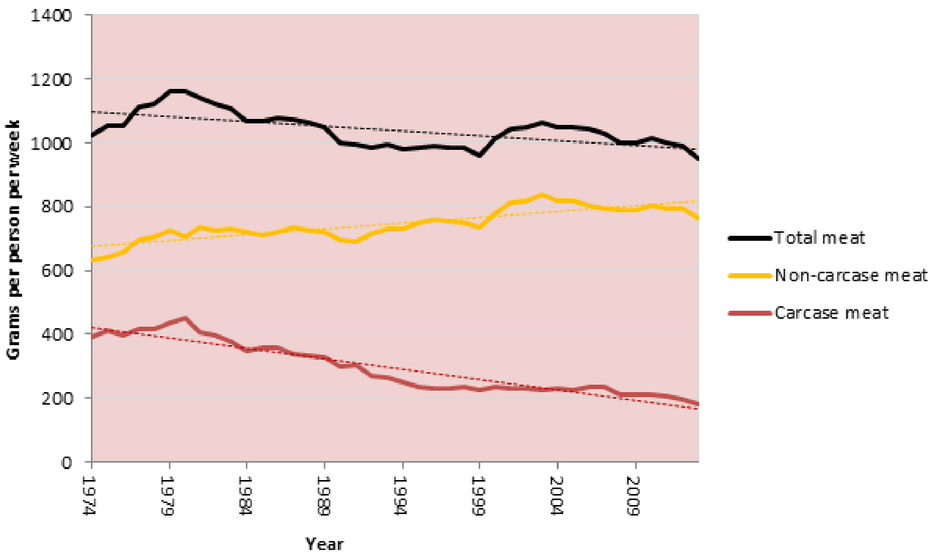

Figure 3: UK meat consumption 1974-2013 (source DEFRA)

If this prospect re-opens the issue, the question remains: what are the diet assumptions that make agroecology plausible? Are they realistic?

1.3 Modelling an agroecological UK

Such questions, dealing with the ins and outs of agroecology, have already been studied at EU28 scale in the Ten Years For Agroecology research carried out by IDDRI and AScA, with support from a scientific board consisting of 9 researchers with scientific who gave valuable inputs to the research.

The key characteristic of TYFA has been to quantify the biomass flows stemming from agroecological assumptions – they will be further developed in the present document. Those physical outputs have been put against the needs resulting from the generalisation of an average diet designed to be both compatible (i) with the set of dietary guidelines and (ii) with agroecology, in the sense that it keeps a place for meat and dairy obtained from ruminants in the overall supply. An important feature of TYFA is to assess the production capacity with regards of nitrogen flows, which are identified as a critical limiting factor in organic farming.

The main findings of TYFA at EU level shows that the widespread adoption of agroecology, and the phasing-out of vegetable protein imports leads to an induced drop in production of 35% compared to 2010 (in Kcal). Nitrogen supply only from N fixing crops (legumes) has many environmental positive outcomes but limits the overall production. However, while this loss of production can be seen as a major drawback, its positive side results from the phasing-out of synthetic inputs and the generalisation of biodiversity friendly farming systems. In short, this scenario:

- provides healthy food for Europeans while maintaining export capacity;
- reduces Europe's global food footprint;
- leads to a 40% reduction in GHG emissions from the agricultural sector (an unexpected result that will further discussed in the report);
- regains biodiversity and conserves natural resources.

Such outcomes can only be obtained through the change towards a diet with less proteins of animal origin, thus reducing the needs of feed production.

However, those findings have been elaborated at EU28 level, averaging many production patterns and considering Europe as a broad farming and food system. In short, the above findings are valid in average at a broad scale, but until now, they needed to be downscaled in order to check whether the broad conclusions still hold when considering the variety of EU agrarian systems. In short, are the average yields used at UE level consistent with a finer analysis, at territorial level? To what extent the nitrogen balance carried out at this level does not hide surpluses in some place that may wrongly cover shortages in another place? What are the territorial variations of the overall model sketched at EU level? Such fine grains questions have recently been addressed in a territorialised version of TYFA, that will be presented in the following pages.

The present report is thus based on an analysis carried out at such territorial level in a UK perspective. Scaling down at this level addresses the questions set out above, in section 1.2: does the assumption of generalising agroecology – and healthier diet - in the UK leads to dangerous zone for the food balance? Does it hamper any climate ambition? In detail, does it hold its biodiversity conservation promises? Does it limit any afforestation perspective due to a high demand on farmland?

The following pages are presenting the approach undertaken in order to address those questions and highlighting the main findings, with regards to the challenges faced by UK farming. They argue how agroecology is a plausible and holistic way to address them.

2 APPROACHING THE CHALLENGES OF THE UK FOOD SYSTEM THROUGH AN ORIGINAL MODELLING DESIGN

2.1 The challenges of the UK food system

The UK food system is representative of both the strength and weakness of modern agriculture and consumption. Firstly, it largely disconnects the consumption (demand) and the production (supply) rationales, setting the high productivity and efficiency issue of feeding the UK population in a wider open market perspective, like all other developed countries. Indeed, the UK has positioned itself in a two folds food market: the core EU one and the wider rest of the World one.

It is not the main issue of the present report to further develop the challenges that the UK food system needs to address, this has been made by further reference studies. For our sake, they can be summarised as follow:

- Providing better food to its population, meaning less animal proteins - the UK intake being 100 g, while the nutritional benchmark is around 50 g, less sugar and more fruits and vegetables for the main aspects. On a qualitative stand, it also means shifting towards less processed and better-quality food and reducing exposure to pesticides. Indeed, the spread of diseases such as obesity – for which the UK has the highest prevalence -, diabetes II and cardio-vascular illnesses strongly associated to food behaviour show how the current UK diet is unsustainable[ii].
- Restoring genuine biodiversity management, not only at the fields margins (hedges, landscape features) but inside them, being crops or permanent grassland), and rough grazing, which means adoption of low-input farming practices in absolute terms, and not only "better, efficient use".
- Addressing climate change mitigation, considering the methane and nitrogen dioxide components and land use change (carbon storage through afforestation and trees planting/growing).
- Addressing climate change adaptation through diversified farming systems, enhanced living soils, development of landscape features limiting drought, exposure to wind and soil erosion. Wooded features, agroforestry and silvopasture are identified means in this perspective.
- Keeping the food balance in a safe operating zone, meaning at minimum keeping the deficit in the same range of order. And from a wider perspective, limiting the risks of offshore impacts, by reducing the soya import to start with.

All these challenges can be considered independently to some extent. And they can also be weighted differently. For example, an Intensification path combined with a less rich diet proposes a strong package for a more balanced diet on nutritional dimensions, climate change mitigation, and improved food balance at the end (more production and less imports). However, as mentioned in the introduction, it leaves unanswered the food quality aspects and biodiversity management resulting in an overall loss of biodiversity.

Agroecology presents itself as a good candidate for addressing the blind spots of Intensification , notably in terms of quality and biodiversity. But it is suspected to be weak when it comes to climate change mitigation and food balance, with anticipated offshore impacts at the end. The central issue in terms of production then is: even considering a drop in demand that would result from a change in diet, is the generalisation of agroecology, with its lower yields, compatible with a demand for sustainable land?

In order to assess how these challenges can be addressed – or not – by agroecology, we developed a modelling platform called TYFA regio, which we will describe in the following sections. This platform can be downscaled at UK level in order to address the food balance issue at the end. Taking its origin from TYFAm biomass balance model, TYFA regio simulates different EU and in our case UK food balances based on various assumptions on human diets, cropping and livestock systems.

2.2 TYFAm

The development of the original TYFA scenario[iii] was based on a biomass balance model called TYFAm. TYFAm presents a similar structure as some other simulations platforms designed over the last 10 years such as Agribiom, GlobAgri and SOL and employed in well-known foresight exercises[iv] (Figure X). TYFAm's input variables are the human and non-human demand for food, a waste coefficient, the cropping and livestock systems and the exported surplus for some specific food commodities (cereals, wine and dairy products). As output variables, TYFAm provides the crop and livestock productions, the land use and the nitrogen use efficiency in 2050. For these variables, TYFAm respects three basic balances:

- A commodity balance: (human food, animal feed, seed, industry)*waste coefficient = production – surplus;
- A feed balance: feed available ≥ livestock feed requirements;
- A nitrogen balance: nitrogen inputs to cropland > nitrogen outputs of cropland.

TYFAm employs the European Union of 27 (2007-2013)[1] as unit of analysis. This region is studied as the "European farm", an aggregate without any direct consideration regarding its functioning or its internal heterogeneity. This aspect has two implications. First, only flows between the EU and the rest of the world are taken into account. Second, all the reasoning is based on average values for the EU, whether for production (yields and livestock feed to output efficiency) or for consumption (diets).

[1] The EU-27 region adopted in TYFAm includes the UK and does not include Croatia.

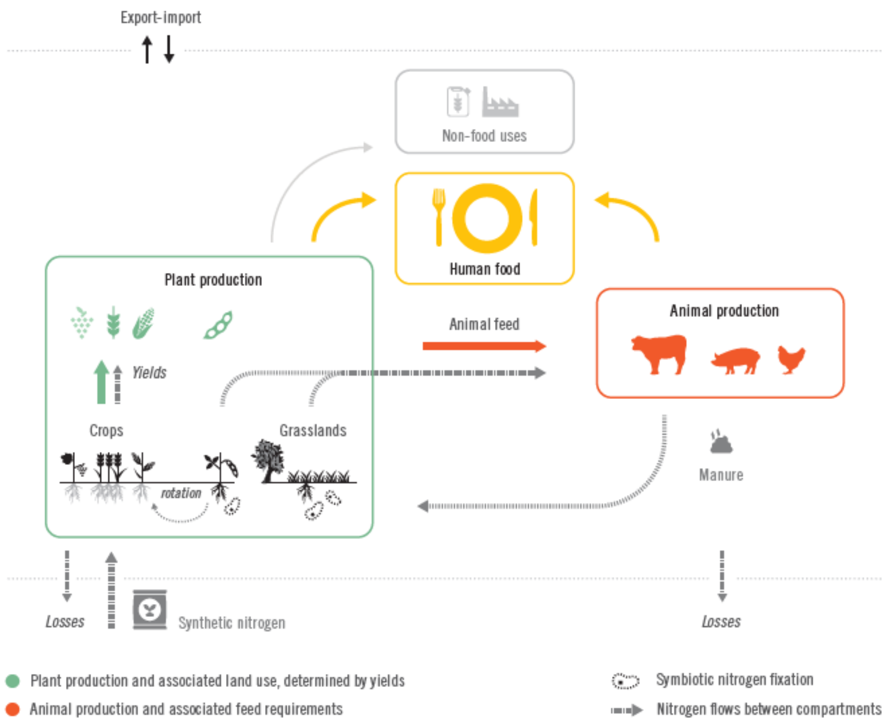

Figure 4: rationale structure of TYFAm

2.3 TYFA$_{regio}$

Aware of the limitations of TYFAm regarding the inclusion of the landscape and the agricultural production heterogeneity of the "European farm" and the need to close the nitrogen cycle at a fine territorial level, we pushed forward our modelling effort and developed a more spatially explicit simulation tool: TYFA$_{regio}$.

We present the region approach as an intermediary level of analysis able to connect both local/landscapes issues with macro issues. TYFA$_{regio}$ consists in allocating grassland, livestock and crops land use across 21 agrarian regions in order to test whether the nitrogen balance is respected as well as the overall production needs set at the EU level by the TYFAm simulation tool, considering the spatial variability in yields ().

While the core conceptual model is mixed farming, the issue is to introduce more diversity in the European agrarian systems. This means bringing herbivores (and grassland) in regions that are today specialised in crop production and to despecialise grass based regions, in order to meet the crops (and in particular cereals) needs. When reading the results provided in this report, the reader should have in mind that the approach is not based on an explicit constrained optimization method. Findings are a plausible model solution among a set of wider possible combinations meeting TYFA$_{regio}$ hypothesis.

Based on Eurostat data at NUTS2 level, 21 archetypal European agrarian systems are characterised following the criteria of land use, yields and yield potential, total production - including grass, density and type of livestock and total animal production (Figure 5). In accordance with TYFAm settings, we chose 2010 (as an average of 2005, 2007, 2010 and 2013 in order to reduce variability) as the reference year to define the European agrarian systems. Then, we applied the TYFA hypothesis to configure the evolution of these systems to 2050. Three broad kinds of regions appear from the regionalisation process: ager, grass and mosaic/mixed systems. The first group refers to the regions where the space dedicated to crops is relatively higher. Among these areas, we can find regions where the dominant crop is wheat or barley (ex. Ager in most of Poland or in Baltic regions) or maize used as fodder (ex. plains in the south-west of France and north of Italy). In the second group, grassland dominate the agricultural landscape. Regions in this group can be quite heterogeneous varying from alpine or Mediterranean areas with extensive grass production, to higher grass yield areas favoured by an Atlantic climate and located in North-West of Europe. Finally, in the third group, we have mosaics, highly concentrated in the Central Europe, and mixed systems more disseminated all over the continent (ex. most of Spain excluding the Atlantic coast, boreal regions in Finland and Sweden, Mediterranean hills and highlands). Regions in this category present a balanced share of cropland and grassland. The main difference between mosaics and mixed systems is the scale to which the association of crops and livestock intervenes. In mosaics, this association is local, while in mixed systems it takes place at a broader level.

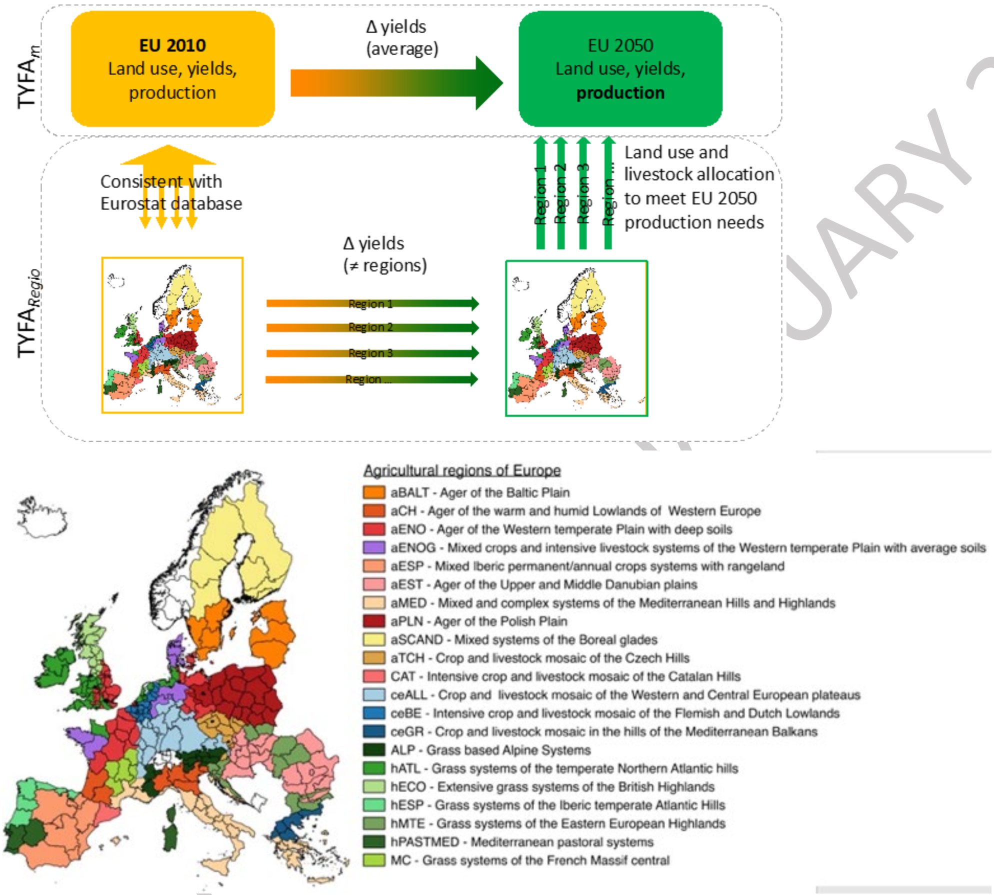

Figure 5: Structure of TYFAm and TYFA$_{regio}$

2.4 From $TYFA_{regio}$ to TYFA UK

Figure 6: division of the UK using $TYFA_{regio}$ regions

When looking at the UK, three $TYFA_{regio}$ regions belong to that area: the Ager of the Western temperate Plain with deep soil (aENO), the Grass systems of the temperate Northern Atlantic Hills (hATL) and the Extensive grass systems of the British Highlands (hECO) (Figure 6).

aENO is located in the Eastern part of UK covering most of England. hATL system covers the south western part of Great Britain and the Northern Ireland. hECO region finds its place in the northern part of UK and more precisely in Scotland and northern England.

We are aware that each of the three regions hides a greater heterogeneity between its borders than the one suggested by TYFA regio territorial breakdown. For example, in hATL, in counties such as Dorset, Wilts, Cheshire and Sussex, we can find areas in which arable land clearly characterises the landscape. hECO shows the same kind of huge variations between the fertile and productive arable land of South-East and the rough grazing of the Highlands. Other notable variations could be noted in each region.

However, we must keep in mind that just as other models of this kind, TYFA regio functioning is based on average values for parameters such as yields or livestock densities and that the variability inside a regional type is less than between two regional types, in average. To this respect, the size of the statistical units is a key factor: the bigger they are, the more likely they are to average different types of farming. Despite their downsides, these averages let us interpret more clearly the results in terms of the contribution of every region to the aggregated outputs such as the land use or the national food balance. In addition, a certain level of simplification becomes necessary in order to define assumptions for the evolution of the UK agricultural systems in 2050, which can be consistent from both a domestic and a European level.

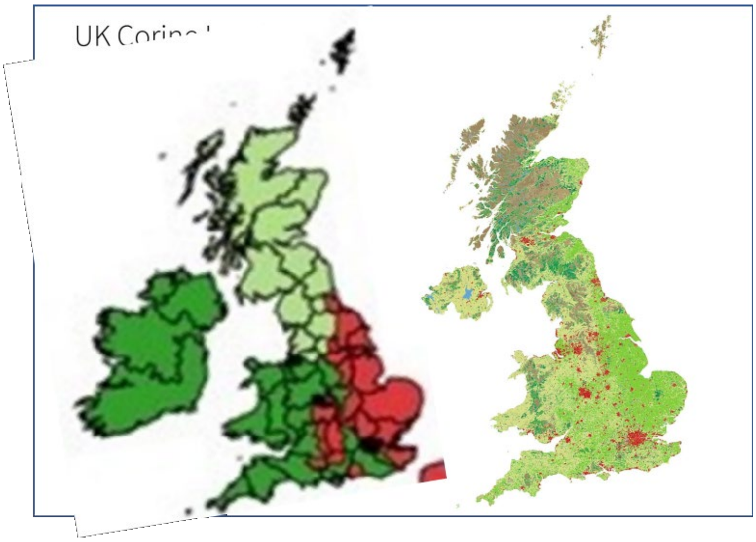

Figure 7: There are variations in terms of land use inside TYFA regio UK regions, but these variations are lesser than those between regions, having in mind the boundaries of Nuts 2 units (right map displays Corine Land cover land use – red areas in Corine map is urbanised areas).

Having this caveat in mind, aENO, in average, is characterised by deep fertile soils, which allows a high yield potential for crops such as wheat and barley. Thanks to the rich rainfalls provided by the Atlantic climate and the presence of deep soils, in hATL we find a high yield potential for grass and cereals. The presence of livestock (cattle and sheep) defines the area. Finally, the Because of the combination of high latitude and altitude, in hECO crop production is constrained in average. As a result, large permanent grassland areas grazed by sheep and cattle dominate the landscape.

At this point, a careful reader would have probably noticed that while hECO system is a UK peculiarity, aENO and hATL are shared with other areas in continental Europe (ex. aENO system in the Parisian basin in France). For this reason, we employed a specific methodology based on two stages to "reconstruct" the UK agricultural system starting from TYFA regio regions. The first step consists in extracting the UK system from the original European region based on coefficients taken from Eurostat such as the share of UAA for agricultural production, the share of LU for animal production. For example, UK share's is 24% of aENO UAA, 21% of aENO arable and 27% of aENO herbivores livestock units in total. UK represents 43% of hATL UAA, arable and livestock units of all kind. On the basis of the shares of the different UK regions, we recombined the three systems in order to have a unique UK unit for our analysis. The main condition for this methodology to work is that we have to check that the UK system is close to the "parent" region In Europe. We checked this hypothesis found a strong resemblance between the two systems (UK's share and all EU), with caveats for sheep and dairy cows. Sheep were over-represented in UK and beef under-represented while the dairy cows where over-represented if compared to the baseline data taken from Eurostat[2]. For this reason, we used a correction coefficient in order to rebalance in the UK the number of these two animal herds. Despite this "internal shift" (replacing beef with sheep), all other key variables in terms of land use, yields and overall herbivore density are close enough to carry on the analysis based on interpolation of EU modelling results to each UK types and, in a second time, summing up the results at a national UK level.

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[2] This situation origins from the British traditional specificity of using a higher share of sheep production (relatively to beef) for wool and human consumption than other regions in the continental Europe. On the other hand, the presence of cattle has been reduced in the UK due to competition from Ireland.

2.5 Data sources for TYFA UK baseline

Setting the baseline for the UK needs to mobilise further databases, accordingly to TYFAm and TYFA regio structure.

Regarding the regional land use, livestock structure and detailed production outputs (yields), we used EUROSTAT database set at NUTS 2 level. This statistical level divides the whole UK into 40 different units grouping districts in England and Northern Ireland, unitary authorities in Wales and council areas in Scotland. 2010 is the reference year accordingly with the whole TYFA regio database used for modelling at EU scale. It should be noted that this EUROSTAT database only covers the Agricultural Usable Area of farms, thus leaving apart the use of commons (around 1.2 m ha) which could not be properly factored in our model. This gap represents between 4% of all UAA in England and 10% in the three other nations and, respectively, 8% and ±12% of all permanent grassland+rough grazing.

As for food balance, we have used the DEFRA statistical yearbook 2018, covering 2017. We have used more recent data set at national level, in order to be more accurate regarding the import/export discussion, for which ten years old data might have been a bit out of date. There is thus a slight discrepancy between the sum of regional production structure and the overall food balance, but the broad figures are matching in terms of overall production and land use, leaving the reasoning robust.

As for diet, we have used FAO diet database for the year 2017, which is setting apparent diet at UK level. This is the database commonly used for international comparison, and the one mobilised for TYFAm. The reader must be conscious that there are significant variations in diet profile amongst different databases (e.g. NDNS, AHDB) depending on the methodology (inquiries vs. apparent statistical statement; methods for sampling; accounting what is in the plate – home, restaurant or catering - or in the shop basket), thus making the intercomparison of different studies sometimes difficult.

All in all, we had to manage various databases, the intercomparability of which is not always very straightforward, which is common in this type of exercise. However, This does not prevent us from carrying out the reasoning, and but one must be aware that we are working on orders of magnitude with a certain margin of uncertainty. Therefore, even if the raw results are indicated with a certain degree of precision, to the nearest hectare or ton, one must be cautious about keep a certain distance about their meaning. This precaution does not mean that the analysis is false, but that conclusions based on this it remains general. and relates to orders of magnitude for which we can ensure overall consistency.

3 THE ASSUMPTIONS OF THE MODEL

3.1 Towards a sustainable and sober diet in 2050

One key element in the TYFA scenario is the adoption of healthier and more balanced food regimes. In this scenario, we applied to the UK the TYFA sustainable diet and based on the nutritional recommendations of the latest EFSA advice (EFSA, 2017a).Since the actual UK food regime is in broad terms close to the EU average one, we decided to use the same human diet for the UK and the EU in 2050[3]. In summary, the way towards a sustainable TYFA diet for the UK is comparable to the one for the average EU citizen.

The TYFA diet is built on a combination of three drivers: nutritional benchmarks, existing eating habits and environmental challenges (biodiversity and climate change). It has an average caloric requirement of 2300 kcal/person/day[4] based on the current age pyramid and a normal level of physical activity. The protein intake is 50 g/day/person with a maximum of 35g for animal protein. The carbohydrate share ranges between 45 and 60% of total caloric intake with a limit of 100 g/day/person for sugars. The lipids are between 30 and 40% of caloric intake, while the fibre requirement is at least 30g/day/person. Relative to the current average UK diet, this leads to a slightly lower caloric food regime with a reduction of the shares of animal products and sugar and an increase of the shares of vegetable proteins, fruits and vegetables (Figure 8). In order to maximise the nitrogen provision to crops and the protein intake in feed, TYFA diet allocates an important share to protein crops such as legumes. At the same time, since cereal-based poultry and pig feed consumption directly competes with human consumption, it minimises the role of monogastric animals in meat consumption. At last, as TYFA aims to maintain extensive grasslands and protect biodiversity, it leads to the stabilisation of bovine and ovine meat consumption.

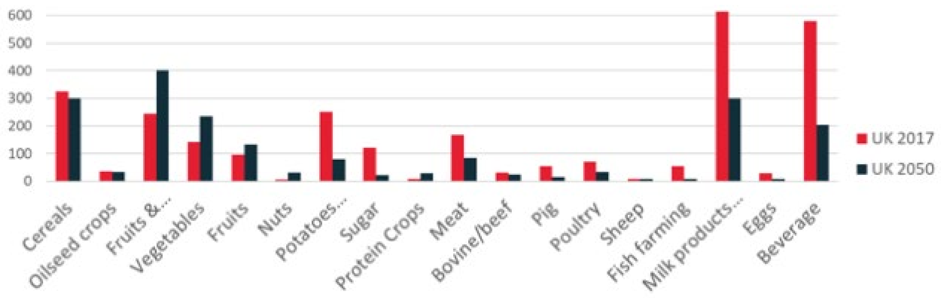


Figure 8: UK diet in 2017 (source ; FAO) and in TYFA UK 2050 (g/day)

In terms of overall impact of needs at the UK level, resulting from average changes in the individual diet, this food regime is associated with a 10% waste improvement in the model and a notable increase of UK population relative to 2010 (from 65.8 million inhabitants to 77.5 million in 2050, according to the medium projections from the Office for National Statistics). The waste improvement coefficient in the model is voluntarily modest in order to focus on the agronomic dimension of the agroecological

[3] In average, the UK diet is close to the EU28 one, except for significant products correlated with overweight issues: potatoes, beverages and sugar. As for animal products, the consumption is slightly above the EU average.

[4] This amount of calories represent the effective caloric intake. It does not include any kind of waste which is computed separately in the model.

scenario. Alternatively, an assumption of -20% in waste (like the Courtauld Commitment) or further, like the -50% in the CCC report on Land Use Policy for a Net 0 emission sets -50% waste by 2050[v], would have been more satisfactory in terms of policy consistency, but would have blurred the signification of the outcomes at the end (what is the share explained by the improvement of waste management or by the agronomic assumptions?).

3.2 The agroecological assumptions

The Figure 9 summarises the agroecological assumptions of the TYFA scenario. Though they have been set at an EU level, their principle remains valid to configure TYFA regio.

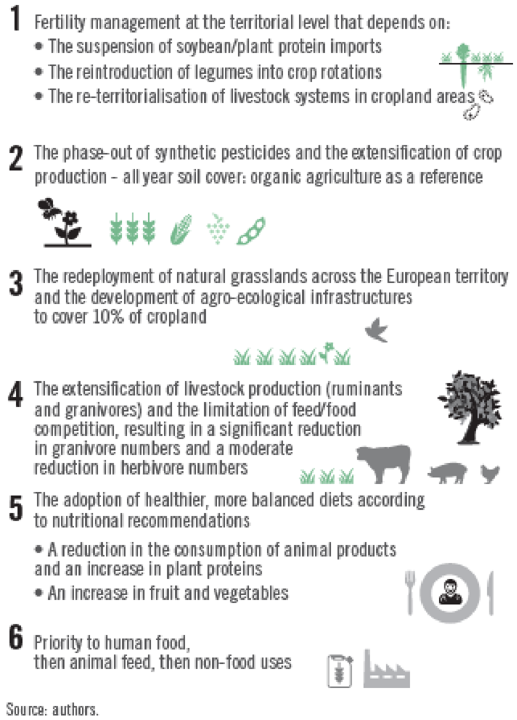


Figure 9: the set of assumptions used in TYFA

We adopt the agronomic side of these assumptions, used as entry variables in the model and thus set out here in order to propose a logical path in the model. They have been designed from an environmental result-oriented point of view. Such assumptions derive from what is needed for the sake of a sound biodiversity and natural resources management by farming, using a kind of "backcasting" reasoning of what would be the agronomic conditions for a biodiversity rich agricultural landscape. The extensive set of work developed in the field of High Nature Farming literature can be quoted as a source of inspiration.

A key aspect for the development of TYFA is achieving the fertility management at a fine territorial level. This ambitious objective requires a combination of different conditions to take place. First, we stopped vegetable protein imports since they are a cause of imported deforestation and they are often produced using methods not allowed for EU and British farmers and thus creating an unfair competition (ex. GMO soybeans imports). Second, to close the nitrogen cycle and provide nutrients to the plants without recurring to synthetic mineral fertilisers, the reintroduction of legumes in crop rotations becomes essential well as the association of crops and livestock. This second aspect allows important fertility transfers between the animal and the vegetal production. The phase-out of mineral fertilisations has several positive aspects. It contributes to lowering the risk of eutrophication of aquatic environments, alteration of soil life processes, fungal diseases and weed development in plots and drinkable water contamination. Furthermore, since nitrogen application on arable land represents a third of agricultural GHG emissions, reducing the fertilisation in the cropping systems is a key element in climate change mitigation.

TYFA extensification of cropping systems relies also on eliminating synthetic pesticides (insecticides, fungicides and herbicides). Multiple arguments explain the choice to abandon pesticides such as improving the health conditions for agricultural workers, eradicating traces of pesticides in food and water, protecting biodiversity and declining the emergence of resistances to new molecules.

The absence of synthetic fertilisation and pesticides makes TYFA similar to organic agriculture with regards to cropping systems. For this reason, TYFA assumptions regarding crop yields in 2050 are based on the meta-analysis by Ponisio and al.[vi] focusing on the yield gaps between conventional and organic systems. In order to be consistent with the TYFA regionalisation, we applied two other coefficients to take account of the impacts of climate change and of the different degree of chemical inputs employed today by farmers in various European regions. In the first case, we based our reasoning on the AEE document[vii] regarding the impacts of climate change on ecosystems and society. We thus assigned climate coefficients leading to a relative increase factor of 15% on organic yields in 2050 yields for regions in northern Europe, where projected climate is expected to be positive and we decreased such organic yields of -20% in harsher conditions of southern Europe. In the UK, EEA maps suggests that this climate factor is null for hECO and aENO and slightly positive for hATL. . As far as the use of chemical inputs is concerned, we maintained Ponisio's coefficients for Western European regions having in 2010 a high use of mineral fertilisations and pesticides, while we increased of 20% the 2050 organic farming yields for Eastern and Central Europe regions presenting a lower use of these products and thus lower baseline yields to compare with. The application of this methodology in UK has the result of decreasing the average initial yield of -25% for cereals in aENO and hECO and -17% in hATL for example.

An important space in TYFA agro system is assigned to natural grasslands and agro-ecological infrastructures. Because of their role in biodiversity conservation, carbon sequestration and fertility management through atmospheric nitrogen fixation, we set that permanent grasslands and pastures be extensively managed having a 30% share of (spontaneous) leguminous crops. We also set a share of 10% of UAA for agro-ecological infrastructures such as hedges, trees, ponds, stony habitats and sunken paths.

Just as for cropping systems, we assume that livestock systems in TYFA experience a process of de-Intensification and extensification of animal production. TYFA ruminant systems (dairy, beef, sheep and goats) are characterized by a feed ration based on a limited use of concentrate (cereals and protein crops) and a higher amount of grass from pasture in order to reduce the feed and food competition, preserve grasslands and produce omega-3 rich products with acknowledged nutritional benefits. As a result, ruminant physical productivity (quantity of milk or meat per animal) becomes secondary, in favour of criteria such as hardiness and the ability to eat fodder resources containing more woody species that are available over a longer period. Two dairy systems are modelled. The first one is a grass-fed system spread in regions in which the majority of fodder comes from permanent pastures, typically the Highlands. . For these grass systems, we retain the assumption of 5,000 kg milk/year. The second is a mixed system developed in lowlands and hills, in which permanent pastures is combined with temporary grasslands, cereals and legumes (5,700 kg milk/ year). Both the approaches implicate the reintroduction of more resilient breeds, a longer lifespan in animals (9 years for mixed, 11 for grass fed), the first freshening raised to 3 years and a lower replacement rate with a higher share of slaughter cattle. Beef and sheep systems have an extensive production system with a pasture-based ration.

Since they are in direct competition with human nutrition for cereals, the three TYFA ruminant monogastric systems (pigs, broilers and laying hens) are highly reduced and become an adjustment variable used to restore, if necessary, positive nitrogen balances in TYFA regio. This means that in the 2050 simulation, we distributed these animals in the various European systems in accordance with the final nitrogen balance while maintaining the 2010 proportions of pigs and poultry in the total LU of every region. The technical performances of these animals are modelled using the references of organic agriculture systems in Brittany. Their feed rations take into account the different types of feed according to the age and production cycles, and include oil cakes co-produced by the oilseed and protein crop sectors for human use.

Finally, because of the priority given to human food in the TYFA scenario, this results in the total phase-out of bioenergy crops, neither under the form of biofuel nor that of biogas.

3.3 Farms and farmers in an AE UK: managing diversity and mixed farming systems – playing with ecological landscape features

The above generic assumptions are applicable at different levels of modelling. In TYFAm they have been used at the EU level and in TYFAregio at Nuts 2 level. But they conceptually average a variety of individual farming systems and farmers implementing agroecology accordingly to their genuine local conditions. In short, the display of aggregated results at different levels is meant to represent the combination of individual farming systems. The regionalisation allows a much closer outlook on individual farming systems composing the different agrarian type regions. We can detail in terms of the farming system what is behind these major sets of hypotheses. We can thus characterize different types of broad farming systems for 2050, facing different types of agroecological challenges:

- Those consisting in specialised extensive livestock systems, typically grazing sheep and beef systems in the highlands (most of hECO and some parts of hATL). For such systems, the main challenge stands in the management of the herd accordingly to the natural growing of roughage, limiting the risks of overgrazing and/or poor habitat management. A sound understanding of the variability of semi-natural forage production through space and time, the choice of breeds, with long production cycles, to adapt to climate change are paramount in such systems.
- Those consisting in mixed systems, combining field crops and grass-based livestock systems (dairy, beef, sheep), found in hATL, aENO and lowland of hECO. Their challenges stand in the overall organisation of the farm work, the management of fertility cycles and pest and weeds. Such systems are typical in hills and lowland regions. While important features of such systems are already present today – to start with the mixed nature of the system – clearly the change of scale and labour force organisation (agroecology being more demanding on this aspect) are important points to consider, alongside the longer rotations including the introduction of legumes and protein crops and/or ley farming.
- The mixed nature of farming systems does not need be to be reached at the farm level, and some systems field crop systems or, alternatively, livestock systems can reach a certain level of specialisation, provided that the complementarity between the cropping systems and the livestock systems can be organised at a territorial level (around some tens km maximum to give an idea). Pigs and poultry systems are an interesting variant in this perspective, but the combination of animal welfare needs with the best use of manure – thus avoiding excessive spatial concentration of such

systems – may lead to small-medium systems as compared with today, with more robust breeds and the phasing out of use of antibiotics and low-quality meat, with longer production cycles.

- Vegetable growing is meant to take place in the lowland of each region, where climate allows their cultivation. It stand on a specific rationale in terms of organisation, due to the high demand in labour force. For these production, the challenges are numerous: management of a high diversity of vegetables, fertility transfer through manure imported from other systems and longer rotations – breaking the vegetable cycle with crops/ley farming for example. The scenario envisages a high development of this kind of production, based on seasonal production, which means major increase in labour force and smart territorial settings (fertility management, marketing, support work,…).

In detail, for the previous broad types of systems, the size and share between different types of crops (from cereals to root crops and legumes), forages (from maize, leguminous crops to roughage) and animals (ruminants vs. monogastric) will vary, accordingly to geography, crop and grass productivity and land tenure legacy. Farming in Wales is not and will not be the same as in East England, just to give an example. If de-specialisation towards mixed – vegetal and livestock - systems is the common pattern for agroecology, this mixed nature is far from being uniform.

We have so far characterised the farming systems through their main productions and broad land use categories. However, an important and crosscutting component to consider in the farming systems is the presence of ecological landscape features supporting production. Hence, TYFA UK model assumes that 10% of all cultivated land – including permanent crops – is used for permanent and natural green infrastructures. In total, it might represent around 600,000 ha in 2050 against 330,000 ha in 2010 under the category "fallow land and green infrastructure", thus a +80% increase.

To a large extent, extensive pastures form the bulk of ecological features in terms of area covered. But important services will be provided by hedges diverse in species (local) and ecological structure, the introduction of trees in silvopasture or agroforestry systems (for climate and pest management reasons), the building and maintenance of stone walls and ponds. Eco-engineering, for the choice of adapted varieties, plots and management practices of such ecological landscape features is an important support job for farmers.

4 WHAT WOULD AGROECOLOGY MEAN FOR THE UK?

4.1 The outputs of an AE UK agriculture : land use and livestock

In this section, we analyse the modelling results of TYFA regio in the UK first looking at livestock numbers and then at the land use. In both cases, we compare the 2050 simulation results with the baseline data taken from DEFRA 2017.

In the TYFA scenario, the livestock plays a key role in ensuring the fertility transfers between the grassland and the cropland. Indeed, the livestock level in 2050 in the UK results from a combination of three elements: the above mentioned agroecological equilibrium needed to close the nitrogen cycle at a fine territorial level, the historical livestock trends in the UK and the coverage of human diets demanding a lesser amount of animal products. More in detail, TYFA agroecological assumptions imply a livestock despecialisation for hATL and hECO subregions and an increase in animal numbers in aENO. In the first case, this rebalance is explained from the decision to enhance the contribution of historical pastureland areas to UK food provision. In regions where the grass dominates the landscape, TYFA regio increases the amount of land allocated to crops such as barley, oats or wheat. The shift from grassland to arable land of all kinds (including fodder crops) implies an increase of nearly 400,000 ha, thus +25% of arable land in hATL (moving from 30% of UAA to 37%). This change is indeed striking but it should noted that since the 1950's, the UK as a whole has experienced a *decline* by nearly 1.6 m ha of arable land going along a ruminant specialisation since this period, mostly taking place in this hATL region[viii]. This rather strong assumption might not as disruptive as it may look when considering the longer term. The assumption is thus that formerly arable land turned into improved grassland gets back to arable. In hECO, the change is much less and represents a shift from 19% to 22% of UAA – not counting commons. In the second, we reintroduce the livestock in a region, aENO, where in the last decades we assisted to an increased crop specialization. The resulting balance in land use leads to arable representing 2/3 of UAA to around 57% in 2050 and permanent grassland moving from 1/3 to 40%.

These assumptions have major impacts on livestock units which largely decline in 2050 at the UK level for all groups of animals: dairy cows (-14%), cattle (-23%), sheep and goats (-34%), pigs (-30%) and poultry (-34%) (Figure 10).

Despite, the high GHG emission level per unit of output, a substantial amount of ruminants is preserved as compared with other scenarios addressing climate change through a huge reduction of this category of livestock. Maintaining a production and therefore a consumption of sheep and beef is largely the result of grassland conservation and the extensification of the associated dairy production. The lower productivity per unit of cow means that we need more animals to produce the same amount of milk. In addition, the ratio of dairy beef per kilo of milk produced grows due to the increase in dairy progeny. Indeed, the changes in dairy herd management associated with a higher number of lactations induce a higher number of animals (fattening heifers and calves) generated in the lifecycle of a dairy cow. This goes along a shift back to mixed milk and meat breeds, more able to value grass and other forages.

As far as granivores are concerned, the large amount of ruminants available limits the volumes of meat to be provided by pigs and poultry, which remain within the limits of guidelines regarding animal protein consumption.

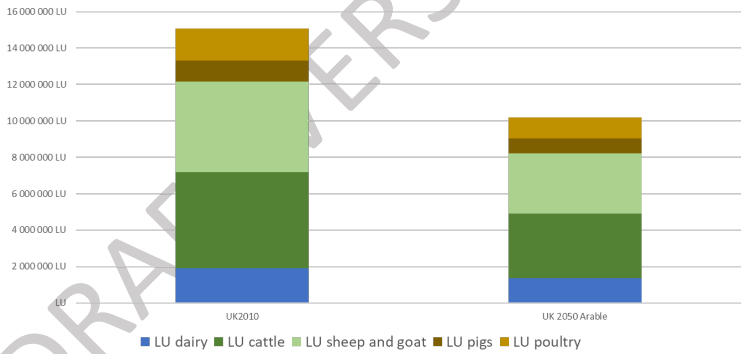


Figure 10: change in livestock units between 2010 and TYFA UK 2050

Following the evolution of food regimes and the despecialisation of crop and pastureland areas, TYFA regio remodels the land use in the UK in 2050 (Figure 11). The areas dedicated to pulses (x 7 for pulses, but the starting point is nearly null), root crops and vegetables (+60%) in the total amount of arable land largely increase, while the areas destined to cereals and oilseed is reduced.(approx.. -5% and -20%) In cereal cropland, we also assist to a better crop diversification. The share of wheat and barley decrease in favour of coarse cereals such as oats and cereal mixes.

The increased amount of fruits consumed by the UK citizens boosts the land use for permanent crops such as apples, pears, plums and cherries and where suitable apricots and peaches. This allows the UK to reach a similar level of land use for fruit trees as in the ’60s – the area in orchards having been divided by 6 since then. For both fruits and vegetables, the assumption is the development of rustic varieties and of seasonal provision, adapted to climate patterns to take place in 2050. These two sectors does not weight a lot in the overall land use at the end, but the development envisaged in the scenario corresponds to major changes in those two sectors as compared with present.

As a result of crop diversification, in hATL and hECO the grassland areas decline (by respectively -30% and -25%) as well as the land allocated to fodder crops (-70%). The relative greater reduction of fodder crops land is explained by the competition that temporary grasslands, fodder maize and leguminous crops harvested green have with permanent grasslands to supply forage to the livestock while providing less ecosystem services such as biodiversity conservation or carbon sequestration. It should be noted that 1/3 of this decline goes to potential other uses and 2/3 to arable. In aENO, the area of permanent grassland nearly doubles, at the expense of arable land.

Fallow land and potential other uses of land (the latter destined to afforestation) also increase dramatically in the TYFA UK scenario (by respectively +80% and a 10 times more in 2050, but the starting point is nearly null by construction) representing altogether 11% of total UAA. It is worth noting the special case of the “fallow land and ecological infrastructures” category, whose ecological function changes between 2010 and 2050. In 2010, this land has an “ecological compensation” justification in a largely intensive agrarian environment. In 2050, all agricultural land is managed extensively based on a variety of crops and types of land use, along with extensive grasslands that play a key role in the ecological structure. Thus, the ecological infrastructures of 2050 complete an agricultural approach that ensures levels of ordinary biodiversity that are already far higher than those seen today as developed below. In practice, some of this land could have a pastoral function and be added to the “permanent grasslands” category.

As explained above, we could not have the data for the use of Commons by livestock and thus calculate the share of forage supplied by them. This means that calculations have been made “leaving Commons apart” in terms of forage contribution, considering them by default as unused in the forage balance in the baseline situation of 2010, while we know it is not the case. The apparent productivity of on-farm grassland is thus overestimated in the baseline and while the change of productivity is calculated in relative terms (as a % of change between 2010 and 2050), the overestimation is maintained in the 2050 projection. This implies that Commons are still needed in 2050 calculation.

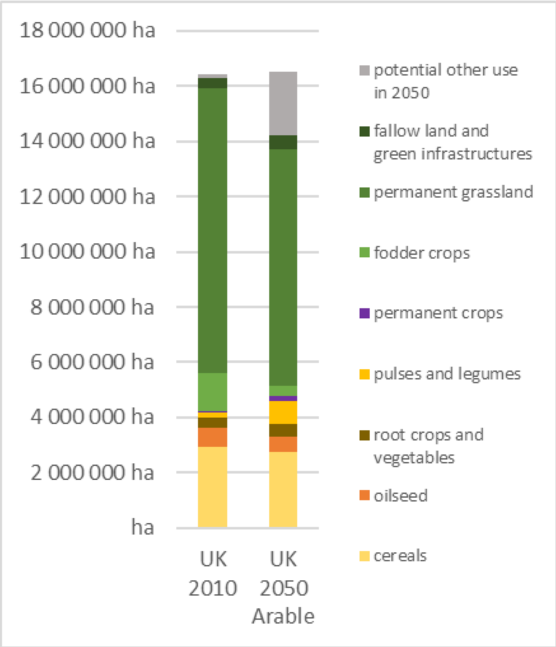


Figure 11: change in land use between 2010 and TYFA UK 2050 – important notice; the figures are only for UAA in farms – Commons are not counted and can be assumed as remaining useful for forage supply

The following figure shows the breakdown of changes across the TYFA UK regions.

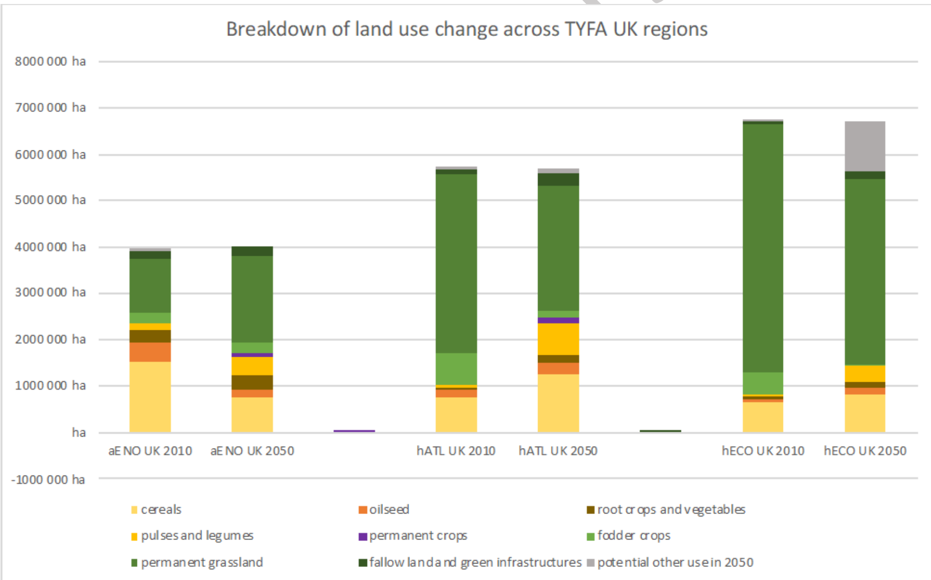


Figure 12bis: change in land use between 2010 and TYFA UK 2050 – same point as Figure 11 regarding the Commons, which are not counted in those figures and can be assumed as still contributing to the forage supply

Generally speaking, hATL and aENO are converging towards a balanced share between arable and permanent grassland. hECO keeps its grassy orientation.

It should be noted that the land use change assumptions, dealing with ±30% of current UAA cannot address the detail of such changes, notably their feasibility and sustainability when coming to the detail of the concerned land. This is due to data limitation and to the granulometry of the analysis. However, long term analysis of land use change in the UK shows that changes of this order of magnitude have taken place, which increases the plausibility of such assumptions in average. But in detail, local peculiarities about soil and relief might alter the feasibility of the average assumption. Thus, without pre-empting of further analysis at finer grain, the above results have to be understood for what they are: average assumptions in average regions.

4.2 Agroecology contribution to UK's biodiversity and natural resources

As already explained, the assumptions of agroecological farming have been designed with regards to a result-oriented outlook. The ecological reading of agroecological farming can thus be carried out unfolding its ecological foundations. Two main intertwined features can be mobilised in such perspective:

- The no synthetic input factor
- The landscape perspective

4.2.1 The no synthetic input factor

In their diversity, all kinds of agroecological farming systems described previously share a common pattern: the absence of use of synthetic fertilisers, notably nitrogen, and pesticides.

As for nitrogen, TYFAregio is calibrated in order to look for a positive nitrogen balance (uptake – supply) positive in every region. For the three regions in UK, the resulting nitrogen balance calculated converges towards 110% in all regions, thanks to the combination of livestock units spatial allocation and the development of legumes in crop rotations and in cover-crops. Such ratios are rather tight indeed and call for a sound management of nitrogen in agroecological farming systems. It should however be noted that the organic nature of nitrogen means a slow release of the amount that can be used by the plant, which limits the yield indeed, but also the risk of runoff due to the scarcity of available nitrogen. This explains why organic nitrogen a radical positive factor is for efficient use, unlike its synthetic form, leading to much lower efficiency rates. In comparison, the apparent value of the same indicator is 200% in average for the UK today (DEFRA), meaning that half of the nitrogen will go into the environment (water, soils and air).

As for pesticides, the radical assumption retained for TYFA (EU or regio) goes along the nitrogen one, as explained above. High level of – synthetic – nitrogen supply calls for pesticide mobilisation in order to correct dysfunctions caused by too rich and too simplified agro-ecosystems.

This nitrogen and pesticides reading is central in order to understand two key features supporting ecological integrity:

- As for the soil component of the agroecosystem, the application of synthetic fertiliser alone alters the development of micro-organism, notably bacteria and mycorrhizae, with impacts on soil life and structure and the capacity to develop nutritive networks supporting plant communities. On the contrary, organic form of nitrogen supports such soil life when combined with carbon supply. Application of pesticides will have enhanced negative impacts on the same soil components. Thus, low level of organic nitrogen supply – and, no need to say, pesticides - appears as a key element for sustainable soil life from a bio-chemical point of view, alongside careful physical management.
- From an habitat perspective, the mixed agroecological farming system consists in transferring nitrogen from non-fertilised pastures and semi-natural vegetation to crops through export by mowing or grazing. The ongoing net biomass export leads to low-nitrogen soils in pastures,

favouring spontaneous leguminous plants and other plant species. This floristic richness, with flowering through seasons, is the main condition for the support of insect communities – including pollinators – and resulting natural food pyramid. The key for such functioning is the ability of semi-natural ecosystems to produce enough biomass to feed herbivores without endangering their fertility, provided that the stocking density matches the natural productivity.

- 

Figure 13: such species-rich grassland results from the management of nitrogen in agroecological farming systems (Source: Wildlife Trust)

This change in management of both crop and pastures would be a major change in biodiversity management of both permanent grassland and crops, that respectively get 150 and 60 kg N/ha/year, thus much above what is consistent with a high biodiversity value.

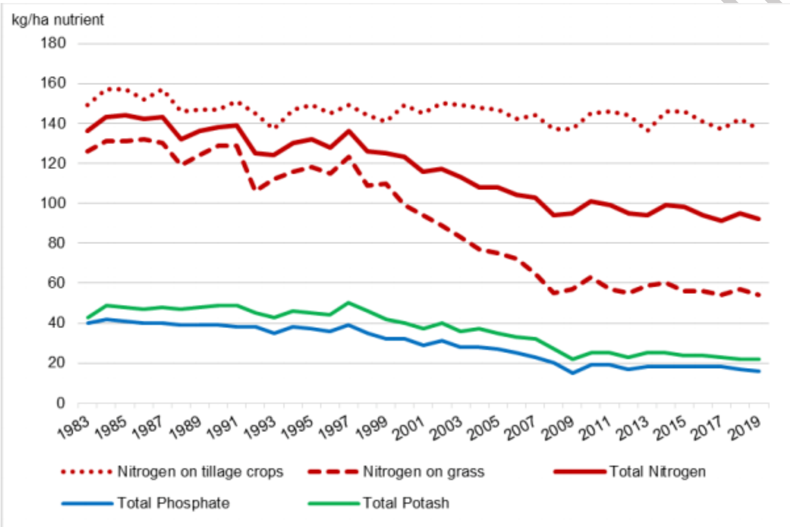
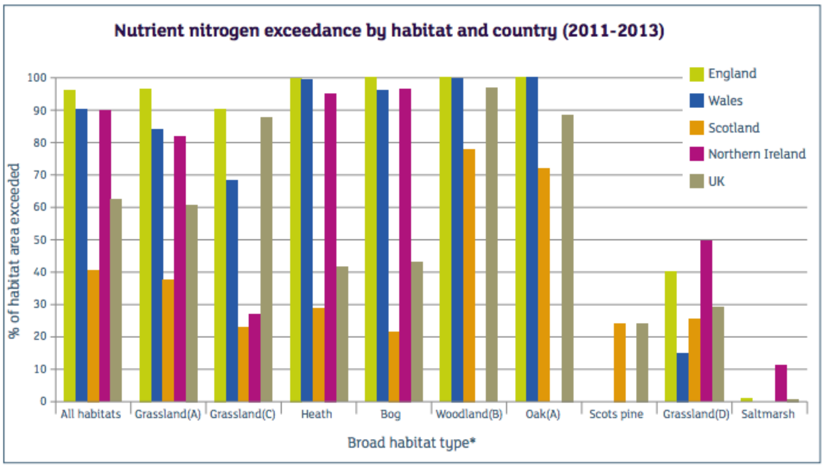


Figure 14: development of fertilisers use on crops and grass (DEFRA agrienvironmental indicators)

No need to further elaborate on the fact that this absence of use of synthetic inputs will have many positive cascading effects on water quality and air quality, while such inputs are the cause of aerial pollution with remote health impacts.



* Grassland (A) – Acid grassland; Grassland (C) – Calcareous grassland; Heath – Dwarf shrub heath;
Woodland (B) – Broadleaved woodland (managed); Oak (A) – Acidophilous oak (unmanaged);
Scots pine – Scots pine (unmanaged); Grassland (D) – Dune grassland

Figure 15:the role of nitrogen in habitat richness or poverty –[ix] why tpday's most UK valuable habitats are altered, and why changing nitrogen management would reverse the trend

4.2.2 The landscape diversity factor

The absence of use of synthetic inputs has major consequences at a agroecological landscape level:

- In places with crops, it leads to a necessary balanced land use between semi-natural vegetation (source of nutrients) and crops (sink of nutrients), thus a first level of diversity in the crop/permanent pastures balance.
- Within the crop component of the landscape, fertility and weed/pest management requirements lead to diversified crop rotations, combining legumes and protein-oil crops, root crops/leys, vegetables,… It also needs to mobilise permanent landscape elements playing a role in pest management (e.g. hedges hosting predators for pests), that thus are a genuine component of the farming system.
- In places dominated by extensive permanent pastures, unfit for crop production, diversity takes place at a finer grain, between different types of grassland and rangeland forming the bulk of semi-natural habitats.

The high biodiversity level of landscapes dominated by extensive, no-input permanent pastures – thus associated with extensive livestock systems - does not need further explanation as they already are identified as the core of High Nature Value farming in the UK today – being in the highlands or in the hills. For readers familiar with HNV studies, we here refer to type 1 HNV farming systems[x], characterised by the dominance of semi-natural vegetation in land use. Furthermore, an agroecological scenario goes further than simply keeping a permanent grassland landuse: the low-input, low stocking density conditions are central in order to maintain or reach high level of biodiversity as explained above. Biodiversity grassland deserts caused by fertilised grassland, early mowing are not part of our image. As a matter of fact, they are not even possible in the absence of synthetic fertilisers and imported feed, necessary to support stocking density above the one allowed by the natural productivity at landscape level.

From a broader perspective, our scenario lower the overall needs in British animal production, leaving room for alternative land use of today's permanent pastures towards afforestation. As stated above in the land use change analysis, our assumptions lead to around 10% of present UAA for such alternative use.

This is for the big picture in such areas dominated by semi-natural vegetation, but the extent and location of such afforestation is a matter of local spatial planning, taking into account ecological and social factors. The idea is not to systematically plant in the most marginal lands large monospecific forests (a dangerous option in a climate change perspective, not to mention their poor biodiversity quality). Though some parts of such marginal lands would be fit for such forest use, but in a diversified and ecological way, there is room for also envisaging forms of afforestation at finer grain, from silvopastoralism for climate change adaptation to afforestation covering some tens of hectares in places where such wooden habitats would bring biodiversity. The diversity of wooden elements in composition and size is a key element for the overall biodiversity richness of the country. Notably, developing large areas of forest would allow the presence of large mammals – deer, boars,…. Indeed, such change goes along a proper management of those animals with farming activities (e.g. sanitary aspects).

The issue is different in mixed landscapes, combining low-input crops and permanent pastures, thus referring to type 2 HNV farming systems. For those, the biodiversity value results from the diversity of low-input land use – crops and semi-natural vegetation, but this later is not dominant in the landscape – and landscape features. As compared with today where these landscapes have a low biodiversity level in the UK, agroecology would on the contrary bring high biodiversity potential, by playing on the different levels explaining species richness. The interpretation of the below archetypal representation of a mixed agroecological landscape will support the demonstration.

Figure 16: an archetypal mixed agroecological farming landscape

Three levels of analysis are needed to fully understand such biodiversity in type 2 High Nature Value farming systems[xi]:

1. Each unit level composing a diversified agroecological landscape – pasture, meadow, no-input crop, no-input orchard, hedge – is able to host a specific plant and animal community by itself. While, for the reasons evoked above, permanent pastures and meadows are amongst the richest components of such a landscape, due to their permanent character, every land use will

have a benefit for some segment of wildlife: hedges for many insects, birds and small mammals; cereals with messicole plants and small animals, orchards, etc.

2. The adjacent habitats character brings another level of biodiversity – called the ecotone effect. For example, a small rodent will spend most of its time in a hedge, but will benefit from a close wheat field to complement its feed. Such complementarity plays at every level of the landscape and it is all the more powerful that the habitats are themselves rich. There is little value in connecting a single-specie trimmed hedge with a high-input wheat field.
3. Lastly, the overall biodiversity quality will be explained by the whole set of units, spatial configurations at the landscape level. The resulting "emerging" richness cannot be explained only by the sum of each unit/ecotone effect, but from a holistic point of view. In this perspective, we find again the potential role of introducing a variety of wooded elements in the landscape as it enriches the agroecological biodiversity potential with a genuine forest component.

This reading of what forms the biodiversity structure and functioning of a genuine agroecological HNV landscape is paramount to understand the difference with an approach based on the development of landscape features leaving untouched the intensive pattern in field. In particular, there exist a trend of thought reflected in the Intensification /land sparing approach, proposing to address biodiversity challenges through the development of ecological features in intensive agricultural landscapes. Thus a dual approach meant to address both climate and biodiversity challenges. This might typically consist in planting trees in field crops for a kind of simplified agroforestry pattern, developing hedges or planting forests. This approach is of *some* interest compared with the same landscape without any wooded element. But it cannot achieve, by nature, a really high level of biodiversity because it lacks the very basis of a rich agroecosystem: the richness of each of its component, based on micro-life to start with. Without this fundamental layer of micro-life – bacteria, funghi, insects, earthworms,… — there is no capacity to have a full food chain. A tree in a monoculture landscape will offer a good refuge for a bird of prey, but what if there is no small animal to catch? Here we come back to the intrinsic need to have low-input farmed landscapes. This explains by the way why we cannot hold on the simple fact that typical British landscapes combine grassland and cropland as it is the case today, how scenic can they be. We need to go further.

For biodiversity, the loop is complete: from input management to landscapes, to landscapes to input management.

Hence, the observed decline of the index of plant species richness in most valuable habitats (stream sides and neutral grassland) could be reversed in such a scenario, with positive causal chain on other biodiversity indicator such as butterflies and farmland birds.

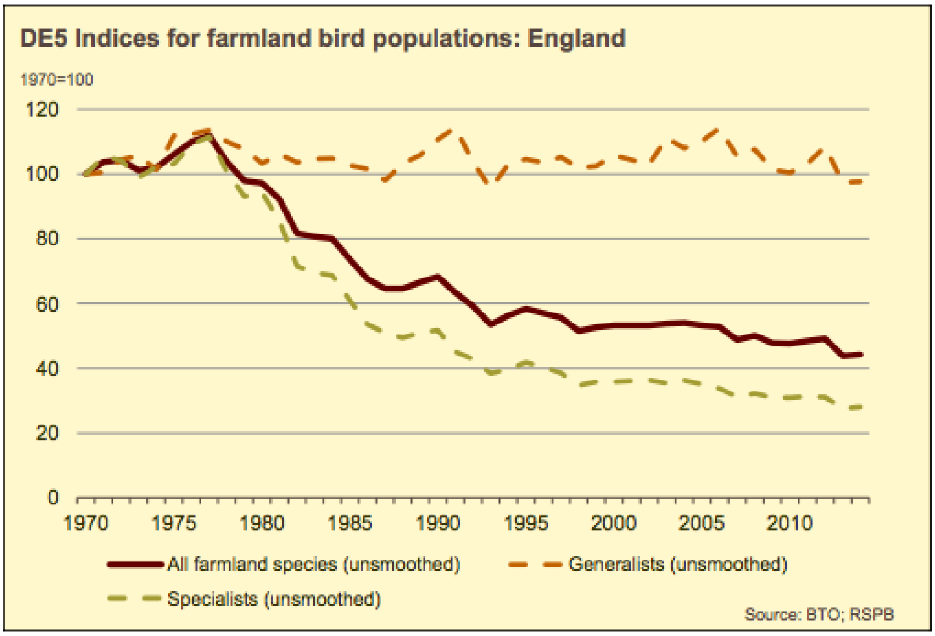


Figure 17: improving both input and landscape management through agroecology would turn the curve of farmland bird index up (DEFRA agrienvironmental indicator)

4.3 Climate change: when agroecology delivers for climate

In this section, we analyse the impact of TYFA UK scenario on climate change. Firstly, using the ClimAgri® calculator[xii], we measure the difference of GHG emissions between the baseline in 2010 and our simulated scenario. Secondly, based on a literature review, we estimated the carbon sequestration potential for the land use change envisaged in TYFA UK.

4.3.1 The reduced livestock population and the agro-ecological farming practices curb GHG emissions

We assessed the impact of TYFA UK scenario in terms of GHG emissions and carbon sequestration potential using the ClimAgri® calculator. Rather than restricting itself to the UNFCCC categories, ClimAgri® measures agricultural GHG emissions in a sectoral and comprehensive way. As such, all emissions pertaining to the functioning of the sector are assessed, from upstream to downstream. Direct emissions include "classical" non-CO2 emissions (CH4, N2O) coming from soil management, manure management and enteric fermentation and CO2 emissions associated with energy consumption at the farm level. Indirect emissions include CO2 and non-CO2 emissions originating from inputs fabrication as well as energy provision to upstream activities.

Under the hypotheses mentioned above regarding the implementation of TYFA UK scenario, direct and indirect GHG emissions originating from agriculture decrease by 38% (Figure 17). In addition, since vegetable protein imports are brought down to zero in a context where a significant share of those proteins comes from deforested areas in South America, the total emissions reduction could even be higher.

One of the most important sources of GHG emission reduction (N2O and CO2 in particular) results from the phase-out of chemical fertilizers, and nitrogen in particular. In the UK, in 2010, emissions from agricultural soils represented almost 25% of total direct agricultural emissions. By eliminating the use of synthetic nitrogen and by significantly improving the level of nitrogen use efficiency, N2O emissions linked to the application of nitrogen to soils significantly decrease (-53%), while emissions linked to the fabrication of nitrogen are brought down to zero.

Emissions from manure management also significantly diminish (-72%). This decrease mostly comes from the reduced number of livestock and the evolution of manure management practices for the bovine herd, notably the disappearance of liquid forms of manure following the increase in the use of straw. Emissions reduction are less important in absolute terms for sheep, pork and chicken systems (-2 Mt CO2eq compared to -4 Mt CO2eq for cattle), but significant in relative terms (-77% compared to -69%).

Emissions reduction linked to enteric fermentation is around -28%. This decrease could even be greater if we did not decide to maintain an important ruminant population in the TYFA UK scenario. This choice is one of the core hypothesis of TYFA regarding the key role of natural grassland in biodiversity conservation, and the need to have a sufficient number of animals to graze those grasslands. However, in order to reduce the amount of enteric emissions, we made the hypothesis that half of the dairy and suckler cows would be given feed additive. These additives are already available and can bring down the level of enteric emissions by 14%/cow— according to the existing literature[xiii]. Yet, they can only be used in semi-intensified bovine herds, i.e., given to animals which spend enough time within stables to allow their feed to be managed. In the TYFA model, the share of cattle under a mixed system that could allow such a feed management practice is 80%. However, we assumed that only 60% of them would be concerned by this change.

Direct emissions linked to the consumption of energy remain almost constant (-2%). Since the idea defended in TYFA is that vegetables production should be seasonal as much as possible, we decided to maintain unchanged the area of heated greenhouses. No further hypotheses were made to increase the energy use efficiency for the heating of those greenhouses, nor for that of livestock buildings or agricultural machinery. It should also be noted that no specific hypothesis were made either to reduce emissions from energy consumption in the agricultural sector through substitution of biofuels with biomass.

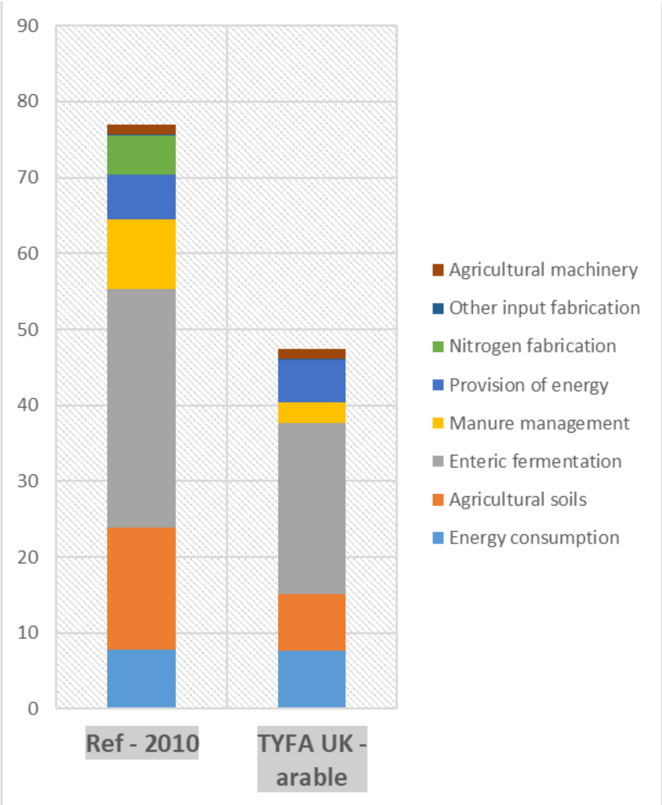


Figure 18: emissions reduction of TYFA UK compared to 2010 (Mt CO2eq/year)

4.3.2 An important carbon sequestration potential through afforestation

Based on coefficients taken from literature (more details in Annex 6.1), we measured a carbon maximal sequestration potential for the TYFA UK scenario, based on the assumption that all land "freed" by the simple cover of domestic needs is used for afforestation. It should be made clear that other options for such "freed" land are possible, including the maintenance of grazed areas for export and cultural issues for example. But such alternative options would not lead to the maximum carbon sequestration potential calculated here and, in addition, would increase the methane emission in proportion of the number of grazing animals.

In this analysis, we need to keep in mind that because of great uncertainties regarding carbon sequestration rates, the evolution of forestland and of its management practices, all data provided in the following section must be interpreted as an order of magnitude.

Our estimation suggests that an agroecological UK could in maximum increase its net annual carbon sequestration by around 47% relatively to 2010 (Figure 18) with 28 Mt CO2 sequestrated, representing 60% of the carbon emissions of the agricultural sector in 2050.

The main source of carbon sequestration comes from forestry. A careful reader will probably remember that, according to our hypothesis, we destined the surplus of agricultural areas originating from TYFA regio (potential other uses land areas) to tree planting (1.7 million ha). As a result, in TYFA UK scenario, CO2 sequestrated from the forestry sector increase dramatically (+93%). This increase is particularly important especially if we consider that actual forest areas will probably decline their sequestration rates in 2050.

We also assigned 10% of UAA to silvoarable and silvopastoral agroforestry (1.4 million ha of agricultural land with a planting density of 188 trees/ha) for their important functions regarding not only carbon sequestration, but also other ecosystems services such as providing shelter for livestock and a habitat for pollinators, improving water retention and the nutrient cycling. In order to model these systems, we made the simplifying assumption that agroforestry does not affect crop yields and does not divert land from agriculture. The carbon sequestration provided by these systems represents around 6% of total carbon storage of TYFA UK scenario.

Grassland and fallow land carbon sequestration also change in TYFA UK scenario relatively to 2010. In the first case, because of the declined pastureland area in 2050, we assist to a slight carbon sequestration reduction (-8%). In the second case, we have an increased carbon sequestration value (+209%) which origins from the greater amount of land destined to green infrastructures.

Finally, we analysed the potential carbon emissions resulting from the grassland areas converted to cropland located in hATL and hECO, which we have set up in order to despecialise these two pastureland subregions. Our estimations show a risk of reducing carbon stocks at around 6 Mt CO2, which represents 17% of the total carbon sequestrated through forestry, agroforestry, grasslands and green infrastructures.

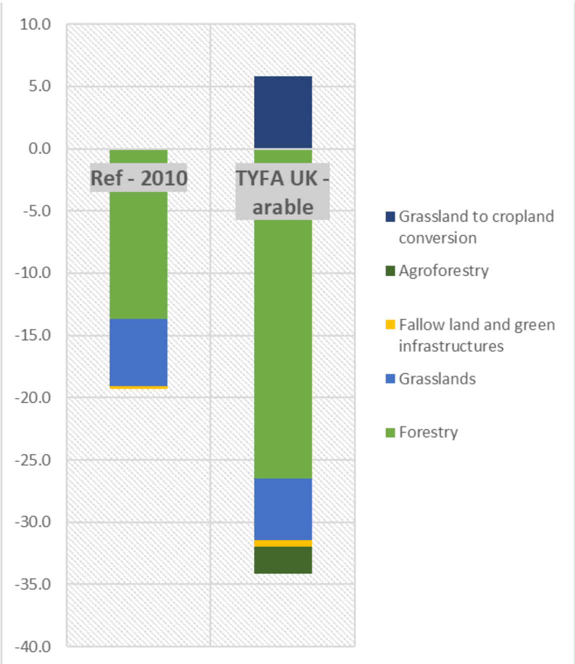


Figure 19: maximum carbon sequestration originate from land use change in 2050 [Mt CO2/year] (assuming that 100% of "freed" land on farms is afforested)

4.4 Thanks to a sober diet, a safe operating zone for an agroecological UK food balance for domestic products

We have been discussing so far the environmental dimensions of our TYFA UK scenario. While the results are generally positive, a question remains: where does it lead the national balance food to? Because of TYFA agroecological system and TYFA regio reallocation of EU crops and livestock, the UK changes the structure of its agricultural production. More in detail, the UK reduces the level of production relatively to 2017 for the vast majority its food commodities. In addition, it should be noted that the UK population is expected to significantly rise by 2050, from 66 millions inhabitants in 2017 to 77,5 millions in 2050 (central assumption of ONS forecast).

The questions are of two kinds:

- To what extent does the reduction of production needs resulting from the change of diet compensate the combination of increased population and reduced yields?
- What is the resulting food balance at the end, taking into account the different kinds of products?

•

The central element in order to make the question even conceivable is the decrease in needs for crops used for animal feed due to the combination of (i) less animals in total (ii) less grain in the feed for herbivores. Otherwise, we would fall in the dead-end identified in the introduction of this document: without significant change in diet, there is no point in discussing the impact of a yield reduction that would mechanically lead to a lack of land.

As for the first question, the following table shows the main changes in production, the supply term of the equation. This results from the combination of the land use change and the assumptions on yields explained above.

	2017 (DEFRA 2017)	2050 (model)	relative change
cereals	23,0 m t	15,7 m t	-32%
protein-oilseed	3,1 m t	4,0 m t	30%
permanent crops	0,7 m t	4,2 m t	463%
vegetables	2,7 m t	5,2 m t	93%
sugarbeet	8,9 m t	0,8 m t	-91%
potatoes	4,9 m t	1,9 m t	-60%
milk	15,0 m t	8,5 m t	-44%
beef	0,9 m tec	0,9 m tec	-3%
sheep	0,3 m tec	0,2 m tec	-34%
pig	0,9 m tec	0,5 m tec	-44%
poultry	1,8 m tec	1,0 m tec	-47%
eggs	0,7 m t	0,4 m t	-47%

Table 1: change in physical domestic output between current 2017 situation and TYFA UK for main commodities.

For the major productions in physical terms, decrease in production are very significant with around -45% for milk and poultry and around -1/3 for cereals and sheep. The maintenance of beef supply results from the extensification assumptions, leading to longer production cycles and at the end more animal/dairy cow as compared with current intensive dairy cows. Relative changes on minor productions in terms of amount in 2017 are mostly noted for fruits and vegetables. As for the former, the assumption is based on the recovery of former area in fruit trees (see above, the land use discussion). For vegetables, the hypothesis is the one of TYFA regio model: 50% of the increase is explained by current situation in 2010 and 50% by the population demand (assuming that local demand will foster local supply). It is assumed that their cultivation is possible at wider scale, provided that the varieties are adapted to climate and soil conditions. This entails a strong reduction in potatoes and sugar beet production that are considered as sharing the same type of deep soil.

On the demand side, the changes are shown in the following table, built on assumptions on diet (see Figure 8) and population change displayed in the previous pages:

Domestic needs	2017 (after DEFRA 2017 food balance sheet)	2050 (after TYFA UK calculations)	Change 2050/2017
cereals	25 314 000 t	13 947 152 t	-45%
oilseed	2 370 000 t	2 270 753 t	-4%
pulses and legumes	3 931 000 t	848 625 t	-78%
permanent crops	4 578 000 t	6 668 572 t	46%
sugar beet	14 050 427 t	650 613 t	-95%
potatoes	6 619 000 t	2 263 000 t	-66%
vegetables	4 769 000 t	8 337 919 t	75%
milk	14 173 856 t	8 486 250 t	-40%
beef meat	1 115 877 tec	707 188 tec	-37%
sheep meat	305 783 tec	254 588 tec	-17%
pig meat	1 422 024 tec	424 313 tec	-70%
poultry	2 050 989 tec	990 063 tec	-52%
eggs	871 585 t	373 269 t	-57%

Table 2: change in physical domestic demand/needs between current 2017 situation and TYFA UK for main commodities.

The bulk of changes in demand result from the lesser animal products consumption. This results in around -40% up to -70% needs for domestic supply for most animal products (at the exception of sheep which intake has been maintained relatively high for cultural and land use reasons, thus resulting in a -17% needs). The reduced needs for cereals and pulses also result from this reduction in livestock consumption. Alternatively, the change in diet entails an increase in the needs for vegetables and fruits. The figure for sugar would need further analysis, as 2017 and 2050 figures are indeed difficult to compare as they are based on different methodologies (apparent domestic balance for 2017 and calculations for 2050). Generally speaking, the balance for sugar is one of the most difficult to analyse as consumption in Europe explains 1/3 of the overall production, ethanol counted.

The following table sums up the aggregated results for the main commodities that can be produced in the UK, comparing the change of overall physical production and the change in the domestic supply ratio.

	2017 DEFRA food balance sheet	2050 TYFA UK calculations
cereals	91%	112%
protein-oilseed	49%	129%
permanent crops	16%	63%
vegetables	57%	63%
sugarbeet	63%	19%
potatoes	74%	86%
milk	106%	100%
beef	81%	124%
sheep	101%	80%
pig	61%	114%
poultry	90%	99%
eggs	86%	107%

Table 3: change of domestic coverage between 2017 and 2050 resulting from both supply and demand changes
The color code indicates the range in which stands the domestic coverage, from dark orange (high deficit) to green (balance) and blue (potential for export)

It should be reminded that the above figures have to be considered in broad terms. They give an order of magnitude that the background colour illustrates, but should not be accounted for too precise outcomes, where a 91% in 2017 is compared with a 112% in 2050 if we take the example of cereals. The correct interpretation of the table is: for cereals, we go from a situation in which UK is nearly balanced, to another one in which it might become a minor exporter.

Having this caveat in mind, the conclusion is that despite the decline in production, except for vegetables and fruits (forming the "permanent crops" item in previous tables) that increase their production, the UK remains in a safe operating zone in terms of food dependence because of its healthier and less rich food regimes. The final food balance is remaining in the same range of coverage or improving for the majority of commodities, except for sugar, for which the degree of external dependence will increase. Except for this commodity, the offshore imprint of UK food system is reduced. In particular, the 3 Mt of imported soya can be phased out due to the combination of lesser animal production, the shift towards autonomous forage systems for ruminants and the supply from domestic protein-oilseed crops. This results that at the same time, the UK can maintain unchanged its present amount of agricultural land and its coverage level and transform its agricultural production system with positive effects on biodiversity, greenhouse gas emissions and the protection of natural resources. For some commodities such as cereals, pig meat and oil-protein crops, the UK may even become a net exporter. For pig meat, this surplus of production is explained by the need to employ pig manure in order to rebalance the UK nitrogen cycle (the reader should remember from the previous sections that we employed monogastric animals as an adjustment variable). For oil-protein crops, the surplus originates from reduced oilseed cakes requirements as explained above.

Fruits and vegetables represent an exception to the idea of a full UK food dependence. Despite the upsurge of food production for these group of commodities, the UK remains a net importer. This means that the increase of agricultural production is not sufficient to completely offset the human food demand for these products, which grows significantly as a result of TYFA healthier diet.

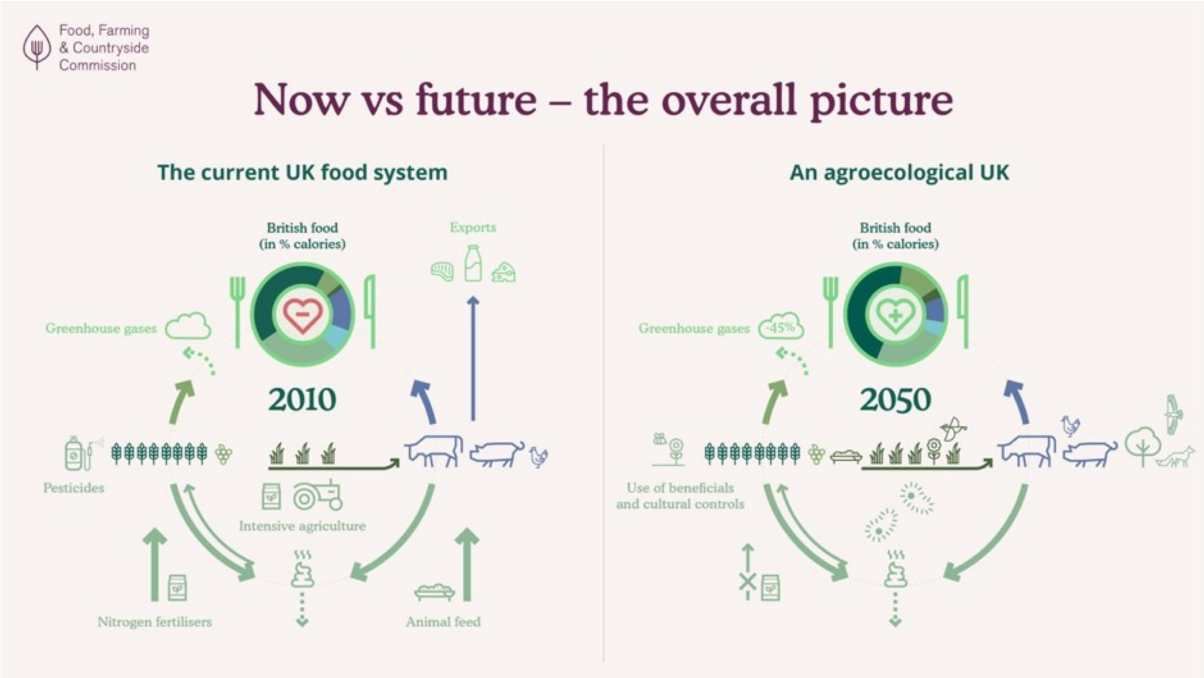
From a broader perspective, it should be noted that the food balance resulting from the set of assumptions used in our modelling exercise keeps a certain balance between crops production, and notably cereals, and animal productions. For those main productions in terms of calories supply and land-use, our assumptions result in a safe operating zone, near to a domestic balance. Note that is balanced outcome is not a forcing assumption as such nor an end in itself (for example, it would make no sense for a country like, say, Belgium in which the population density is too high). But there is a point in trying to achieve a domestic balance for both sectors at the same time. Another set of assumptions might be to specialise the UK in (grass-fed) animal production, leading to more exports in this sector, while reducing the grain production, leading to more imports. But this looks a second best option for two intertwined reasons:

- Animal specialisation in UK would leave unused manure in another place in the World, where there might be a need to fertilise crops.
- Thus leaving the duty to produce cereals to another place in the World reopens the case for offshore impacts, which are difficult to trace and can be avoided through mixed farming.

All in all, apart from sugar, the agroecological assumptions do not worsen the overall UK food balance – which otherwise would question the offshore impact of extensification – on the contrary. We here insist on the fact that this unexpected outcome results from the radical change in human diet, and illustrates the lever effect of reducing animal products in it. The phasing out of industrial livestock rearing, unable to meet social demand in terms of environment, animal welfare and human health (omega 3, antibiotics) is a plausible narrative supporting such an assumption, consistent by the way with the stronger reduction in pig/poultry production compared with the ruminant one.

The food balance discussion stands in the range of products that can currently be produced in UK. The conclusions do not cover all what is imported from tropical countries (coffee, cocoa, tea,…) and/or that cannot be produced domestically with the same quality. For example, the fruit balance is balanced in overall amount per capita, but this does not prevent trading a good UK apple against a good Italian orange. And the discussion about the sustainable import of coffee, for example, goes beyond our field of analysis and does not alter our conclusions in broad terms.

4.5 TYFA UK scenario in one glance



5 ENVISAGING AE IN A UK CONTEXT – SECURING THE FUTURE

5.1 Agroecology is a credible desirable option for the UK – provided a major change in diet

The original modelling of agroecology carried out in this study brings new elements in the current debate about agroecology/organic farming feasibility and opportunity in a dense country like the UK. At first glance, the project of upscaling agroecology in the UK, making it the reference for paving the future, might appear as a sympathetic but irresponsible. So many driving forces seem to call for increased production and yields – from "feed the world" narrative to climate change mitigation based on productive, yet efficient farming – that conceiving a less productive path is immediately disqualified. No need to make further calculation when the equation seems to be: agricultural land is at best maintaining, population is increasing, non-food agricultural use as well. The only solution then seems to be the increase of production.

In fact, there is another term in the equation which reopens the debate: the production needs resulting from the diet. On this aspect, there is a considerable room of manœuvre resulting from a strong reduction in animal products consumption. This point meets all the works conducted in the field of global sustainable food system, highlighting the need to halve the share of animal proteins in our diet in order to keep in the planetary boundaries. The agroecological agenda for UK shares this fundamental requirement. Our diet changes are very similar in TYFA compared with other scenarios addressing climate mitigation. On this aspect, we are no more, no less disruptive than for example the assumptions of the CCC report – for reasons evoked above, our assumptions are less ambitious regarding waste reduction – but this does not alter the whole conclusions. Thus the physical feasibility of agroecology completely rely on this assumption. However, it should be emphasised that compared with other analysis in this domain, our approach has the particularity of leaving a great share of ruminants in the halved animal protein supply because of their central role in the agroecological ecosystem functioning. Without them, the non-edible feed would remain unused and, we would miss their capacity to transfer organic fertilisers from semi-natural vegetation to crops.

Having this diet change in mind, the modelling forming the backbone of the present report concludes that the generalisation of agroecology at UK scale results on an improved food balance at the end, while delivering where productive but input-demanding farming fails – being sustainably intensive or not. Agroecology delivers on natural resources management, on soils life, on biodiversity, on landscapes and, last but not least, on health. As a matter of fact, this holistic delivery is its reason to be. Phasing out synthetic pesticides and synthetic nitrogen is not a minor assumption: it is the key for addressing the environmental and health challenges that modern agriculture is facing. In a much holistic and robust way that the efficient promise which consists in an obligation of alleged means rather than on an obligation of results when it comes to biodiversity management in particular. On this aspect, agroecology outperforms any other path for UK farming, because it proposes a biodiversity management which is not rejected at the margin of the field – what a land sparing approach proposes – but which is constituency of the farming system.

Climate change mitigation is another unexpected outcome of the modelling: despite the maintenance of a certain level of methane-emitting herbivores, all the more extensive, agroecology in the UK might result in a strong reduction in overall emissions. This result is explained by the strong decrease in the use of the other emitting source of farming: nitrogen, all the more under its mineral form that is more volatile that the organic form mobilised in the fertility management of agroecological farming. Ruminants emit methane, but through this process they are able to transform nitrogen in semi-natural vegetation into valuable fertiliser. Combined with this use of climate efficient source of nitrogen, the decrease of production explains the good climate change mitigation performance of TYFA UK. The less agricultural production with an incompressible "embedded nitrogen load", the less overall needs of nitrogen at the end.

5.2 Why agroecology is not a "back to the fifties" scenario

At first glance, our agroecological scenario might simply look like a rewind back to the fifties, where mixed farming and no-chemical inputs was the common pattern. And where local fruits and vegetables also were grown instead of hugely imported fruits.

Indeed, agroecology gets inspiration from the pre-chemical farming, where farmers had to produce without external inputs, or very few of them. And indeed, a lot of the biodiversity heritage linked to agriculture – the high nature value component of UK farming — is rooted in history. Indeed our assumptions consider a reduction in yields while they have been increasing for the last 60 years. All this might give the false feeling that agroecology is not modern and thus not fitted to address modern challenges.

Let us start from the production discussion. Our yields assumptions are based on the meta-analysis of organic yields carried out by Ponisio in 2015. We have used this reference work to calibrate our yield assumptions, adjusting them accordingly to climate change projection (with plausible average positive impacts in the case of UK). This results in an average yield of 5.7 t/ha for cereals in TYFA UK 2050 against around 7.8 t/ha today. But it was 2.5 t/ha in the 50's. The same range of change takes place in the dairy sector where we assume a 5.2 t milk/cow/year against 7.9 t milk/cow/year today. But this 5 tons a cow was the UK average in the early 90's and one could guess that it was close to 3 in the 50's. The average organic yield has increased and has to increase because of incomparable knowledge and technology as compared with half a century ago. The much better understanding of soil live – with the rising domain of micro-life and nutrients flows in underground networks – and of biological control – in a wide landscape ecology perspective – opens up on scientific revolutions able to support increased agroecological production, while keeping central the requirement of absence of use of synthetic-inputs. Precisely, this requirement is justified by recent holistic understanding of such inputs on ecosystems, from biodiversity and climate perspectives. Conceiving a synthetic pesticide-free agriculture is not a past oriented project, it is on the contrary looking towards future in order to address the challenges that our modern societies have to face. In this field, research on N fixation and improvement of legumes of all kinds is a paramount sector to investigate to enhance agroecological production. Let us remind that the nitrogen fixation is at the end, a command variable of the overall productivity of agro-ecosystems freed from synthetic nitrogen.

Thus the understanding of agroecology in TYFA UK is not based on a reasoning freed from production constraints, proposing a nice ecological farming model that would put yields and production as secondary issues. The outcomes of TYFA stand because the assumptions on yields are reasonably high. Without such yields, we would need revise the outcomes in terms of overall land use, where one can conceive a significant share for ecological features and afforestation – another modern component of TYFA inspired by the climate change agenda.

5.3 Revisiting the agroecology vs. Intensification discussion: the risk assessment dimension

This document opens on a justification of agroecology against the shortcomings of Intensification in terms of biodiversity and health impacts, in relation to the use of pesticides and synthetic fertilisers.

The modelling of TYFA UK has shown that the criticism against agroecology in terms of insufficient productivity and resulting excessive demand in land are unfounded, provided changes in diet.

Here we would like to come back to the productivity discussion. We have been explaining that TYFA being a less productive scenario as compared with present, and all the more with the promises of intensification does not mean that it does not consider productivity as a key issue.

But still, while our calculations suggest that agroecology is a credible option, it does not fully demonstrate that Intensification is not another credible option. One can consider the socio-economic robustness of Intensification as a major asset against its poor biodiversity performance. Indeed, high level of production supports food and biomass industries and does not lead to the adventurous shores of agroecology in this domain.

Let us be clear: the prospects of Intensification in terms of production are not necessarily pessimistic, and one can trust the potential of genetic, machinery and precision farming to achieve both production and efficiency. But our intention in the debate is to point (i) that there are risks on production to be considered, based on sound science (ii) and that if Intensification looks like the continuation and improvement of the current high input farming model, the fact that it delivers higher yields in a close future is not a business as usual ongoing trend assumption, it is a disruptive one that needs to be consolidated if we read Figure 1 displayed at the beginning of the document. Wheat yields are no longer increasing, and they are showing more and more variability. And this is not explained by a lack of increased use of technologies and better use of inputs but likely, by agronomic dead-ends caused by pests and soil dysfunction combined with extreme climate events.

If we consider the production risk as a credible assumption for the future, it leads to revise the whole narrative of SI. Its advantage against agroecology is the promise of efficient farming, generating economies of scale and delivering for agri-food and biomass industries. But if the production is not reached, the whole chain of socio-economic advantages is put at risk: efficiency might turn to seeking of input-insurance limiting the variability, economies of scale might turn to public support in order to prevent lower returns than expected and the needs to cover costly investments and, at the end, the viability of industries.

Of course, this is only a hypothetical risk analysis, but considering the baseline situation, it is not unrealistic and should be considered.

In comparison, the agroecological scenario is based on a decrease of production and does not try to maximise the production efficiency for capital intensive economic models. On the contrary, room of manoeuvre is kept open for increased in biodiversity, improved landscapes and alternative land use. This is likely to sustain yields in the short and medium term. It looks thus conceptually more robust, even if not exempt from risks on the production dimension. Compared to SI, it can be argued as being less risky in the longer term, even if the promise in terms of overall production looks less attractive. Indeed, it opens on not yet fully defined socio-economic models – although local markets and medium industries show the way for a credible food chain – but it would be risky not to fully explore them. At least, what we can conclude from this report is that their development at a large scale would not endanger the sustainability of the UK food system, nor its offshore imprint.

6 ANNEX

6.1 Coefficients used to estimate the carbon sequestration potential for various land use changes

	tCO2/ha/year	Source
Forestry Existing forest before 2010 Post 2010 forest	0.9 13.2	IDDRI treatment from Thomson et al. 2018
Grasslands	0.55	To be completed PMA
Fallow land and green infrastructures	0.55	To be completed PMA
Agroforestry	1.6	Same carbon sequestration rate as "post 2010 forest" multiplied by a factor, which takes into account the different plant density between agroforestry and forest systems
Grassland to cropland conversion	-7.6	Poeplau et al. 2011

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