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Agroecology and carbon neutrality: what are the issues?

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The latest IPCC report[1] sets the objective of achieving carbon neutrality by 2050, 2070 at the latest. The sustainable intensification of agricultural production, in a land sparing logic, is most often considered as a necessary step to achieve this. In contrast, this *Issue Brief* questions the potential contribution of a more extensive agroecological food system (i.e. land sharing logic). It rests on a comparison of the TYFA (Ten Years For Agroecology in Europe) scenario with the agricultural component of recently published scenarios achieving carbon neutrality by 2050,[2] using a multi-criteria dashboard. The objective of climate mitigation is put in the broader perspective of transitioning towards a sustainable food system, taking into account the challenges of human health, conservation of natural resources and biodiversity, and adaptation to climate change.

1 https://www.ipcc.ch/sr15/

2 European Commission (2018). *A European long-term strategic vision for a prosperous, modern, competitive and climate neutral economy*. European Climate Foundation (2018). *Net Zero By 2050: From Whether to How*.

KEY MESSAGES

The TYFA scenario is based on the generalisation of organic farming (abandoning synthetic pesticides and fertilizers), the extension of agroecological infrastructures and the adoption of healthy diets, to feed 530 million Europeans by 2050 (despite a 35% drop in production). It leads to a 40% reduction in GHG emissions (35% for direct non-CO_2 emissions), offers a potential for soil carbon sequestration of 159 $MtCO_2$eql/year until 2035, and a reduction of bioenergy production to zero. The scenario is thus not easily compatible with the objective of carbon neutrality, but offers many co-benefits: biodiversity, natural resources, adaptation, health.

A variant of TYFA, TYFA-GHG (for greenhouse gases) improves these performances with a view to achieving carbon neutrality, while conserving the core assumptions of the initial scenario. Emission reductions reach -47%, the sequestration potential is similar, and bioenergy production amounts to 189 TWh/year. TYFA-GHG is based on a greater reduction in bovine livestock (-34% compared to 2010, compared to -15% for TYFA) and the controlled development of anaerobic digestion using grassland grasses and animal manure as feedstock.

In contrast, carbon neutral scenarios rely on a land sparing approach: increases in agricultural yields enable to free up land that is either afforested to increase the biogenic well or used to produce biomass energy. However, assumptions on yield increases seem very high (up to +30%) if one considers, on the one hand their recent stagnation in Europe (particularly for cereals) and, on the other hand, the potential impacts on biodiversity and soil health. Those impacts could indeed call into question the very productive capacity of agroecosystems and thus lead to lower yields rather than higher ones.

This *Issue Brief* proposes a framework for discussing scenarios designed with distinct perspectives. The aim is to ensure that political debates regarding decarbonisation pathways of the agricultural sector will (i) better integrate biodiversity and soil health issues (beyond a single carbon metric) in order to (ii) reconsider strategies based on land sharing and agroecology as credible ones.

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1. THE MITIGATION POTENTIAL OF A MULTIFUNCTIONAL FOOD SYSTEM: FROM TYFA TO TYFA-GHG

The TYFA scenario was developed to explore the conditions under which a generalisation of agroecology, based on more extensive and multifunctional agroecosystems, could be possible. It relies on a modelling tool simulating the functioning of the European food system in terms of basic biophysical constraints (nitrogen cycle, feed-food balance). The main assumptions tested in the scenario are: the generalisation of organic farming, the extension of agroecological infrastructure, the redeployment of permanent grasslands and the adoption of healthier diets (in particular less animal products and more fruit and vegetables). These hypotheses were defined in order to jointly address the key challenges the European food system is currently facing, including the increase in chronic non-communicable diseases associated with food, impacts on, and of, climate change on agricultural systems, biodiversity loss and the degradation of natural resources (soil, water).

Despite a 35% drop in production, the TYFA scenario would enable to feed 530 million Europeans more sustainably by 2050 while generating a surplus in cereals, dairy products and wine. It would also reduce direct and indirect GHG emissions by around -40% compared to 2010 (-35% for non-CO_2 direct emissions using the UNFCCC framework), and offer a soil carbon sequestration potential in arable land and grassland of 159 $MtCO_2$eql/year, at least up until 2035. Bioenergy production based on agricultural feedstock would however be reduced to zero, as almost all the land would be used for food production due to lower yields. Such characteristics (and in particular the fact that residual emissions of the agricultural sector would still amount to around 60 $MtCO_2$eql/year) make the TYFA scenario difficult to reconcile with the objective of carbon neutrality.

To explore the possible contribution of an agroecological Europe to this objective, a variant of the scenario, TYFA-GHG, has been developed. It borrows some assumptions from scenarios that are more climate performance-oriented from the outset than TYFA, while maintaining the latter's fundamentals in terms of biodiversity and natural resource management. In a nutshell, the controlled and limited development of anaerobic digestion using grassland grasses (and animal manure) allows for a greater reduction in cattle numbers compared to 2010 (-34% compared to -15% for TYFA) while maintaining the area under permanent grassland. Thus, 18% of the biomass of grasslands and 50% of animal manure are used as feedstock for biogas production. The relatively larger decrease in the cattle population explains the significant improvement in TYFA-GHG' GHG balance (-47% compared to -35% for non CO_2 direct emissions), while the development of anaerobic digestion allows for a bioenergy production of 189 TWh. Potential negative impacts of such a development on soil and water quality (in particular through digestate spreading) and the diversity of cropping systems (associated to scale effects given the important investment costs), although difficult to quantify in a prospective manner, can be significant. These two aspects led us not to consider a more substantial development of anaerobic digestion, based for example on cover crops or on a larger fraction of grassland, although the latter would have made it possible to further reduce the cattle population. Without being able to set a precise limit from which the scenario would switch to a bioenergy logic that would change the very nature of the agroecology envisaged, it should be recalled that scale changes the very structure of the sector: TYFA-GHG is not a justification in principle for anaerobic digestion development, but the exploration of a variant that has its interest only at the scale where it is envisaged.

In order to understand the mitigation implications of TYFA/TYFA-GHG, and to compare them with the agricultural component of recently published carbon-neutral scenarios, a comparative framework has been developed. It provides a basis for a more general discussion on transformation pathways towards a sustainable food system (including the objective of carbon neutrality).

2. A "DASHBOARD" FOR A MULTIDIMENSIONAL APPROACH TO THE DECARBONATION OF THE FOOD SYSTEM

Following the methodology developed in the Deep decarbonisation Pathways project,[3] we propose a "dashboard" structured around three themes: drivers of change; emission structure; co-benefits and trade-offs. For each theme, a limited number of indicators allow to make explicit the choices, hypotheses and results of each scenario and thus to compare them systematically. Table 1 illustrates the approach adopted and presents selected indicators for each theme.

This dashboard must be understood in a dynamic perspective: beyond a static comparison between scenarios whose objective would be to define which would be the «best», its objective is to engage a discussion between approaches that are characterized by different starting points, and which have tended–so far–to ignore each other. The objective is to identify in this way the "no regrets" options and the trade-offs to be considered, being as explicit as possible as to their consequences on one or other of the dimensions considered.

3 Waisman, H. *et al.*, (2019). A pathway design framework for national low greenhouse gas emission development strategies. *Nature Climate Change*, 9 (4), 261-268.

TABLE 1. A dashboard for a multidimensional approach to the decarbonation of the European food system

Themes	EU LTS	NZ 2050	TYFA
Drivers – Human diets (caloric intake, ratio animal / vegetal proteins, ratio ruminant/monogastric meat) – Yields – Carbon efficiency (kg CO_2eql/tons) – Land use change – Food waste and losses (in % of the production) – Trade balance (in tons)			
Mitgation – Emissions reduction – Carbon sequestration : (i) agricultural soils ; (ii) forest ecosystems – Fossil carbon substitution : energy production from agricultural feedstock			
Co-benefits and trade-offs – Biodiversity and natural resources (area under natural/extensive grasslands, share of agroecological infrastructures, pesticides/synthetic fertilizers uses) – Human health – Climate change adaptation (level of diversification of farming systems)			

Note: EU LTS = scenarios belonging to the Long Term Strategy of the European Union ; NZ 2050 = net-zero scenarios developed by the European Climate Foundation.

3. TWO "FAMILIES" OF SCENARIOS WITH DIFFERENT STARTING POINTS

The scenarios analysed first rest on two different logics.

Those proposed under the European Union's long-term strategy (EU LTS) and the Net Zero 2050 study (NZ 2050) seek primarily to achieve a deep decarbonisation of the whole economy. They rely on yields increases through the intensification of agricultural systems and (secondarily) on changes in diets (less animal products, especially ruminants). The objective is to free up agricultural land to either afforest it—and thus increase the biogenic sink—or use it to produce bioenergy. In this land sparing approach, increases in yields (for both animal and cropping systems) play a central role. The productivity gains envisaged are based on the adoption of technologies that are deemed to also limit (or even reduce) the environmental impacts of agricultural systems, in a context where these same impacts are today very significant.

The TYFA/TYFA-GHG scenarios were constructed in order to test the credibility of a generalisation of agroecology on a European scale. They consider changes towards more thrifty diets and more extensive animal and plant production systems as key (and complementary) levers to meet the challenges of natural resources management (soil and water), biodiversity conservation and human health. In such a land sharing approach, the extensification of farming systems makes it possible to simultaneously *reduce* total GHG emissions—although the level of carbon efficiency of production is only slightly improving—and *restore* natural resources and biodiversity.

The characteristics of the food systems resulting from these two approaches are logically quite distinct. While TYFA's compatibility with the objective of carbon neutrality is questionable, the scenario addresses many of the key issues the European food system is now facing.

— In terms of human health, the phasing out of pesticides simultaneously provides safer working conditions for farmers, who are the first to be affected by pesticide use, and healthier food.[4] The envisioned dietary changes, that go beyond simply reducing total and animal calories in order to reduce emissions, but also consider increasing fruit and vegetables consumption and reducing sugar, would also improve consumer health.

— In terms of biodiversity, the extension of agroecological infrastructures—which represent 10% of arable land in 2050—combined with the redeployment of natural grasslands and the abandonment of pesticides and synthetic fertilizers, ensure in TYFA/TYFA-GHG a real recovery of biodiversity through the redeployment of food webs at all scales, from soil to landscape. In combination with continuous soil cover through the development of intermediate crops, TYFA/TYFA-GHG should also leads to healthier soils and water body status to be achieved simultaneously.

— Finally, the significant rediversification of plant systems, the reconnection of crop and livestock systems and the improvement of soil health are key aspects that would contribute to increase the adaptation capacity of the agricultural sector to climate change impacts: increased water stress, emergence of new parasites/diseases, irregular rainfall.

In contrast, the mitigation potential of the EU LTS and NZ 2050 scenarios are, by construction, very high: their net annual sequestration potential (allowing to offsett residual emissions from other sectors) ranges from 83 to 489 $MtCO_{2eql}$. On the other hand, these scenarios are not always explicit on how they plan to address other sustainability issues of the food system, while their negative impacts could potentially be significant.

— In terms of biodiversity, the drastic reduction in the share of agroecological infrastructure considered as «non-productive», as well as in the area under natural grasslands (up to -53% of non-productive areas in EU-LTS, -91% of grasslands in NZ 2050), will not be without effects given the major role that semi-natural vegetation plays for European biodiversity. Besides that, no details are given on the use of pesticides. Given the assumptions of yield increases, these uses

4 While the positive effects on human health of a diet free of pesticide residues are difficult to demonstrate today, several recent studies provide arguments that are increasingly difficult to ignore. See notably Baudry, J. *et al.* (2018). Association of Frequency of Organic Food Consumption With Cancer Risk. Findings From the NutriNet-Sante - Prospective Cohort Study. *JAMA Internal Medicine*, 10 ; Johansson, E. *et al.* (2014). Contribution of Organically Grown Crops to Human Health. 11 (4), 3870.

could at best slightly reduce if we consider technological progress, at worst increase to maintain yields in the face of new resistance and pathogens. The consequences in terms of biodiversity will be important in both cases.
- Similarly, the use of synthetic fertilizers is not questioned, nor are the high levels of territorial specialisation and the imbalances in the nutrient cycles that accompany them. This could result in potentially further degradation of soil life and organic matter content, as well as impacts on surface and groundwater bodies.
- Finally, the issue of the resilience of agroecosystems and production systems is only quickly touched upon; here again, the priority given to yields increases and the poor consideration for farming systems rediversification appear to difficult to combine with an increase in their adaptive capacities.

These limitations can be explained in part for methodological reasons: couplings between climate models and biodiversity models are still in their infancy,[5] and potential impacts of scenarios on soil life /soil structure are difficult to quantify using single / univocal indicators. But they also reflect an implicit hierarchy, as they *de facto* lead to consider the climate issue as the priority over others.

It is however the very realism of some of the land sparing scenarios here analyzed that can be questioned in this respect, given the importance yields increases play therein. The trend towards stagnation in European yields, particularly in cereals, indeed shows that this assumption is by no way not self-evident.

5 Leclere D. *et al* (2018). Towards pathways bending the curve of terrestrial biodiversity trends within the 21st century.

Considering in addition the potential impacts of most scenarios on soil life, and on biodiversity in the broad sense, as well as the low capacity of the resulting agricultural systems to adapt to climate change, it is the very productive potential of agroecosystems that, in the medium or long term, could be called into question, leading in return not to an increase in yields but to their decline. Beyond the question of the hierarchy of objectives between climate and biodiversity, it is the very strategy of climate change mitigation, based on land sparing, that would become ineffective.

4. CONCLUSION: STRUCTURING THE DISCUSSION BEYOND CLIMATE ISSUES

This *Issue Brief* shows that if the potential contribution of an agroecological Europe to the objective of decarbonization is not immediately compatible with the objective of neutrality, it appears substantial and above all provides credible solutions to the other challenges the current European food system is facing.

These same issues—biodiversity, natural resources, human health—have thus to be better considered when developing and discussing climate-focused scenarios for the agricultural sector. This is all the more so since, as time goes by, the possibility of identifying and implementing trajectories considering together all the sustainable development goals is increasingly challenging and is likely to lead us to the necessity to make choices. These should be based on the most transparent possible discussion of the implications of different options. The dashboard logic used here is particularly important in this respect.

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