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Biomass and climate neutrality in 2050: managing scarcity to maintain productive and resilient ecosystems

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The land sector (agriculture, forestry) meets a wide range of social demands, including: food, energy, materials, carbon storage and maintaining biodiversity. These demands are set to increase as a result of the combined effects of population growth, the phasing-out of fossil fuels (and the consequent need for renewable carbon), the need for carbon storage and for restoring biodiversity to maintain the productive potential of ecosystems in a climate change context. Regarding biomass supply, this depends on land sector productivity, which is determined by soil and climate conditions which are themselves affected by global change.

This *Policy Brief* draws on recently published 2050 scenarios to (a) identify biomass supply-demand balances that meet the biophysical challenges of 2050 (climate, food, biodiversity) and (b) highlight the socio-economic and political issues raised by these scenarios.

KEY MESSAGES

To contribute to climate neutrality and to adapt to climate change impacts, action for biodiversity restoration must be prioritized to guarantee productive capacity and resilience. Such action should include a "recomplexification" of forestry systems (irregular forests) and agricultural systems (longer rotations, agroecological infrastructure) and a reduction in the use of synthetic inputs.

These developments, combined with the projected impacts of global changes on ecosystem productivity, lead to the adoption of a scarcity management approach, rather than one of increasing supply derived from an increase in average yields.

The increasing use of biomass for non-food purposes–from the current level of 50 million tonnes of dry matter (MtMS)/year up to 100-120 MtMS in 2050, depending on the scenario–requires the prioritizing of sufficiency in the scenarios analysed:

- reducing the average consumption of animal products by about 30%, to reduce the proportion of biomass used for livestock;
- reducing final energy consumption to limit demand for biomass energy and to allocate it to high value-added uses.

The development of intermediate cover crops would allow a net increase in available biomass of 15 to 20 MtMS/year. The potential need for water, as well as the cost of establishing these cover crops, requires an evaluation of the agro-ecological and economic conditions for their development.

Storage objectives (65 to 75 $MtCO_2$ eql/year) are put at risk by losses in the biological productivity of forests. Achieving these targets requires major changes in agricultural land, including the expansion of agroforestry, intermediate cover crops and hedges, and a tripling of the area under legumes.

A reorganization of biomass flows as envisaged in the scenarios analysed would have significant social and economic, and even cultural, implications that cannot be ignored; dealing simultaneously with socio-economic and biophysical issues thus implies structuring the discussion on transition pathways to ensure that no issues–whether environmental, social, or economic–and no stakeholders are excluded, to make certain that policy decisions are as all-embracing as possible.

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1. THE CURRENT SITUATION1

The land sector of mainland France produces around 310 million tonnes of plant biomass dry matter (MtMS) per year.[2] This production is divided almost equally into four by-products: fodder (77 MtMS), crop residues (80 MtMS), seeds/fruits/vegetables (70 MtMS) and wood from forests and other sources (80 MtMS). Just over a third of this biomass is currently used for animal feed (110 MtMS, two thirds as forage and the remaining third as concentrates),[3] which is then converted to manure (around 15 MtMS) and animal products (meat, milk, eggs). The other uses of this primary production are, in descending order: returning organic matter to the soil to maintain soil fertility (70 MtMS), increasing the stock of wood in forests (40 MtMS), the production of wood materials/energy (30 MtMS), export (30 MtMS), food production–excluding animal products (20 MtMS), and around 10 MtMS (excluding forests) for energy purposes (fuel, anaerobic digestion, combustion, etc.).

The size of the French livestock population ensures it plays a major role in the organization of these biomass flows: animal feed accounts for 45% of agricultural biomass excluding forests (including crop residues). Two thirds of this biomass come from arable land (fodder crops on temporary grassland, cereals and oilseeds), thus competing with human food;[4] the remainder derives from natural meadows as fodder. In total, almost 60% of the UAA of France is used to feed livestock (half of which is natural grasslands which, when managed extensively, provide multiple ecosystem services).[5] Imports (particularly 4 Mt of soybean meal) must be added to this total. In return, the energy output of livestock farming in the form of food products is only a small fraction of the energy input, representing less than 10% of the energy balance.

A significant proportion of primary biomass production remains within or returns to ecosystems: over 40%, or 130 MtMS, as forest wood that is not harvested (just over 40 MtMS), crop residues (stubble, straw, chaff, 75 MtMS) and animal waste (15 MtMS) that is reincorporated into agricultural soils. These biomass returns are essential for soil life, biodiversity and therefore productivity, and also for carbon storage. With this in mind, the target of a 0.4% annual increase in soil carbon stocks has been set; however, on the scale of mainland France, a destocking of soil carbon is underway, which in the long term assumes the ability to increase biomass return to the soil, particularly in arable farming areas.[6]

Finally, the quantity of biomass currently mobilized for energy or material usages is limited: 50 MtMS, or around 15% of the total are used as follows: 27 MtMS in the form of wood energy (i.e. 100 TWh), 4 to 8 MtMS in anaerobic digestion (crop residues, intermediate cover and animal manure, for 7 to 8 TWh), 4 to 5 MtMS of cereals transformed into first-generation biofuels (rapeseed, wheat, beet, i.e. 30 to 40 TWh), and 10 MtMS of wood material.[7]

2. BIOMASS REQUIREMENTS FOR 2050 CHALLENGES

This section is based on recently published forecast projects, namely: ADEME Transition 2050 (specifically scenarios 1 to 3, as scenario 4 does not meet biodiversity objectives),[8] the Négawatt-Afterres 2050 scenario,[9] WWF's 2050 Biomass Strategy, and the French National Low-Carbon Strategy scenario.[10] These scenarios envisage a doubling of the use of non-food biomass, with requirements varying between 100 and 120 MtMS/year in 2050 (compared to 50 MtMS/year in 2020). The additional 50 to 70 MtMS, depending on the scenario, will be composed of 30-40% intermediate crops, 15-20% crop residues reallocated to anaerobic digestion, 10-15% increased wood harvesting, 10-15% anaerobic digestion of slurry, and 10-15% grass.

The end use of this biomass is more than 80% energy, generating between 290 and 380 TWh, which could meet almost 30% of the French requirement in 2050–assuming a 40-50% reduction in total energy demand. The remainder (15-20 MtMS/year) corresponds to a significant increase in the use of materials in certain scenarios (+50%), mainly in the form of wood.

This doubling of the uses of non-food biomass has to contend with four constraints of varying significance.

Firstly, the availability of productive land is decreasing as a result of soil artificialization, which affects 20 to 30 kha/year, increasing pressure on the rest of the land sector.[11]

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[1] The following figures are intended to provide a framework for discussion and should not be considered as definitive.

[2] To this we can add primary products that are in a minority today: vegetation cover and non-forest wood (hedges).

[3] See https://www.flux-biomasse.fr/resultats/sankey_matieres_premieres/France/tms85

[4] Direct competition for cereals; indirect competition for temporary grassland and silage maize, not consumed by humans, but whose surfaces could be used differently. A significant proportion of biomass (14 MtMS) is also derived from grain industry co-products, and is therefore not in competition. On this subject see: Mottet, A. et al. (2017). Livestock: On our plates or eating at our table? A new analysis of the feed/food debate. Global Food Security, 14, 1-8.

[5] Water cycle regulation, natural habitats, symbiotic fixation.

[6] Launay, C. et al. (2021). Estimating the carbon storage potential and greenhouse gas emissions of French arable cropland using high-resolution modeling. Global Change Biology, 27 (8), 1645-1661.

[7] Agricultural biomass used as biomaterials (starch production, bioplastics, etc.) represents a very small fraction of total biomass, albeit significant in terms of value.

[8] ADEME (2021). Transition(s) 2050. Choisir maintenant. Agir pour le climat – Synthèse. Angers, ADEME.

[9] Solagro (2016). Le scénario Afterres 2050 version 2016. Toulouse, Solagro, 93 p.

[10] MTES (2020). Stratégie nationale bas-carbone. Paris, French Ministry of Ecological Transition.

[11] Cerema (2020). Les déterminants de la consommation d'espaces d'après les Fichiers fonciers - Période 2009-2019. Paris, Direction générale de l'Aménagement, du Logement et de la Nature.

Secondly, maintaining the productive capacity of soils requires an increase in the return of organic matter to ecosystems, which will also promote carbon storage in soils.[12] Without technological solutions for capturing atmospheric carbon dioxide and storing it in deep geological repositories, solutions that are currently immature,[13] between 65 and 75 $MtCO_2$ equivalent will have to be sequestered annually by the land sector. However, the latest figures from CITEPA show a halving of the net forest sink between 2007-2008 and 2020 (from 60 $MteqCO_2$ to 30 $MteqCO_2$), and a three-fold reduction when considering the land sector as a whole (from 49 $MteqCO_2$ to 14 $MteqCO_2$).[14]

The third major constraint on land sector productivity is that soil and climate conditions (temperature and rainfall patterns, soil fertility) are being adversely affected by climate change and biodiversity loss: over the past three decades, agricultural yields have plateaued in northern France and fallen in the south, a trend for which changes in practices cannot be held responsible,[15] highlighting the likely impact of ongoing changes. Similarly, the biological productivity of forests is declining (a 4% fall in gross productivity between 2005 and 2019, along with a 35% increase in forest stand mortality).

Finally, this increase in the use of biomass for non-food purposes must be achieved without jeopardizing France's ability to meet its food requirements–which raises the question of changes in food demand.

3. FROM SCENARIOS TO ACTION

3.1. Maintaining productive potential: a priority

Throughout the land sector (agricultural and forestry land), the priority in the face of global change is to maintain the productive potential and increase the resilience of agricultural and forest ecosystems. Actions to be implemented in this regard concern management adaptations: increasing the proportion of irregular forest stands,[16] diversification and the lengthening of rotations. Encouragement is also needed regarding the development of practices that promote biodiversity, particularly in relation to soils, such as drastically reducing the use of synthetic inputs, particularly through nutrient recycling and diversification, and the "recomplexification" of agricultural landscapes through the implementation of agroecological infrastructure–especially the maintenance of natural grasslands wherever semi-natural forms of vegetation are under-represented (i.e. < 25% of UAA).

3.2. More diversified and resilient agricultural land

In the scenarios analysed, the development of non-food uses is based more on use reallocation (see below) than on increased production. Indeed, the often-cited hypothesis of increased production is inconsistent with both climate projections and yield trends over the last 30 years,[17] and with the need to reduce synthetic inputs to enable biodiversity gain and to increase the resilience of agrosystems. This hypothesis is therefore not one that we have addressed in the scenarios covered in this *Policy Brief*. While genetic selection and improved efficiency in the use of inputs will play a role in improving agrosystem resilience in the face of global change,[18] current yields in most systems are close to maximum agronomic potential;[19] maintaining these average yields will already be a remarkable achievement.

The scenarios analysed instead envisage a controlled increase in biomass production through the development of *intermediate cover crops* on arable land. In addition to net biomass production, their development brings other agri-environmental benefits: carbon storage, reduced leaching, symbiotic nitrogen fixation when legumes are used, soil preservation and erosion control, etc.[20] From a strictly physical perspective, an increase of intermediate cover on almost 90% of arable land was envisaged by the INRAe *4 per 1,000* study, i.e. over 15 Mha. Assuming an average yield of 3 to 4 tMS/ha and a harvest limited to 25% of biological production (to ensure a return to the soil and to account for inter-annual variability), an additional 15 to 20 MtMS/year could be mobilized from arable land (30 to 40% of the envisaged additional biomass).

This physical potential must, however, be viewed within a background of: (a) soil and climate constraints: increasingly frequent droughts and heatwaves during the late summer/autumn drilling season make it difficult for seedlings to emerge; (b) the cost of planting intermediate cover crops, both for sowing and harvesting; and (c) the implications of production variability for supplying biogas plants. Achieving the envisaged harvest and valorization of 15 MtMS/year therefore requires major technical and economic support for farmers, and a detailed assessment of economic and agri-environmental conditions.

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[12] Pellerin, S. et al. (2019). Stocker du carbone dans les sols français, Quel potentiel au regard de l'objectif 4 pour 1000 et à quel coût ? Synthèse du rapport d'étude. Paris, INRA, Expertise Scientifique Collective 4p1000.

[13] See p.15-16: EC (2021). Sustainable carbon cycles for a 2050 climate-neutral EU. Technical Assessment Brussels, European Commission – SWD (2021) 450, 60 p.

[14] CITEPA (2022). Inventaire des émissions de polluants atmosphériques et de gaz à effet de serre en France, format Secten Éd. 2022 – Synthèse. Paris, CITEPA.

[15] Brisson, N. et al. (2010). Why are wheat yields stagnating in Europe? A comprehensive data analysis for France. Field Crops Research, 119 (1), 201-212.

[16] Brang, P. et al. (2014). Suitability of close-to-nature silviculture for adapting temperate European forests to climate change. Forestry: An International Journal of Forest Research, 87 (4), 492-503.

[17] See for example: Hawkins, E. et al. (2013). Increasing influence of heat stress on French maize yields from the 1960s to the 2030s. Global Change Biology, 19 (3), 937-947.

[18] See: Gammans, M. et al. (2017). Negative impacts of climate change on cereal yields: statistical evidence from France. Environmental Research Letters, 12 (5), 054007. Their projections, however, are linear and not discussed.

[19] Schils, R. et al. (2018). Cereal yield gaps across Europe. European Journal of Agronomy, 101, 109-120.

[20] Daryanto, S. et al. (2018). Quantitative synthesis on the ecosystem services of cover crops. Earth-Science Reviews, 185, 357-373.

3.3. Economical and self-sufficient livestock systems for more efficient food production

The second most important lever for developing non-food biomass applications is to reallocate biomass that is currently used for animal feed and direct it towards energy uses: co-products of the cereals industry and grass, which could account for 30 to 40% of additional needs. However, such a reallocation necessarily implies a reduction in livestock numbers and therefore in animal production–even if efficiency gains in animal nutrition are envisaged. Thus, the scenarios agree on the need to reduce livestock numbers by 30-50%, towards systems that are less grain-dependent. This should enable the valorization of grassland for ruminants, and of co-products for monogastric animals, but also to change the use of the agricultural land that is freed up as a result: natural grassland can become forest (up to 3 Mha, which in terms of biodiversity impacts would be locally significant), providing both carbon storage and increased biodiversity; while land in production for silage maize and other crops for concentrate feeds can be used for human food and intermediate cover.

To ensure that food needs continue to be met, this reduction in production should be consistent with a move towards more energy efficient practices, firstly by reducing losses and wastage by 50%, but above all by reducing surpluses (with regard to nutritional benchmarks) in the consumption of animal protein–i.e. a reduction of around 30%.

When considering the economic, social and cultural importance of livestock production in France, the sectoral change envisaged, on the basis of the above mentioned biophysical analysis, must not overlook important issues such as: the desirability and feasibility of changes in dietary practices, changes in employment and income in the livestock sector, the sector's trade balance, and the dynamics of the territories where livestock production is currently concentrated. Moreover, this must all be considered at a time when the livestock sector is facing other challenges that are also significant: generational renewal, increased international competition, zoonoses, etc. Only by taking a collective approach to address these issues will we be able to identify solutions that combine physical, social and economic issues, and to meet these challenges.

3.4. Managing scarcity: a governance issue

Beyond the livestock sector, the reorganization of biomass flows envisaged in the biophysical scenarios examined here cannot be achieved without consultation and decisions on policy. An active approach to *scarcity management* must be taken, so that each biomass type can be allocated to the most appropriate applications. Such an approach relies on open and transparent biomass *governance*, enabling fair and shared decisions. The physical data from the scenarios analysed in this *Policy Brief* show that meeting the various physical challenges requires major trade-offs in terms of biomass use, which in turn raises fundamental social issues that cannot be ignored.

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