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RAINFOREST PROJECT SUMMARY

Food and biomass production systems are among the most prominent drivers of biodiversity loss worldwide. Halting and reversing the loss of biodiversity therefore requires transformative change of food and biomass systems, addressing the nexus of agricultural production, processing and transport, retailing, consumer preferences and diets, as well as investment, climate action and ecosystem conservation and restoration. The RAINFOREST project will contribute to enabling, upscaling and accelerating transformative change to reduce biodiversity impacts of major food and biomass value chains. Together with stakeholders, we will co-develop and evaluate just and viable transformative change pathways and interventions. We will identify stakeholder preferences for a range of policy and technology-based solutions, as well as governance enablers, for more sustainable food and biomass value chains. We will then evaluate these pathways and solutions using a novel combination of integrated assessment modelling, input-output modelling and life cycle assessment, based on case studies in various stages of the nexus, at different spatial scales and organizational levels. This coproduction approach enables the identification and evaluation of just and viable transformative change leverage points, levers and their impacts for conserving biodiversity (SDGs 12, 14-15) that minimize trade-offs with targets related to climate (SDG13) and socioeconomic developments (SDGs 1-3). We will elucidate leverage points, impacts, and obstacles for transformative change and provide concrete and actionable recommendations for transformative change for consumers, producers, investors, and policymakers.

EXECUTIVE SUMMARY

The IPBES Transformative Change Assessment (2025) continues to show the centrality of the "transformative change" framing in understanding the action necessary to meet multilateral climate and biodiversity targets. Moreover, the Transformative Change Assessment gives a central role to equity, justice, and the value of nature in facilitating sustainable transformations, by acting as a powerful deep leverage point that aligns sustainability transformations with the values and worldviews communities hold. Scenarios and pathway studies offer a tool for examining ways of acting on this leverage points through visualising futures where climate and biodiversity goals are achieved, and through stakeholder participation and quantification study examining the enablers and barriers to progressing along these pathways.

Nonetheless there remains substantial knowledge gaps in understanding what feasible targets and pathways for transformative change in the global food and biomass system looks like. This problem is compounded in complexity by the fact that there are many differing interpretations of what a just future looks like, and what the appropriate way to value nature is. Actors with differing worldviews and perspectives on these questions will disagree over the nature of transformative change; and likewise, if scenario and models projects do not account for the plurality of justice preferences then they may fail to pull on these deep levers of change (or even galvanise resistance to change) when the vision of just transformation they present does not align with the worldviews of the stakeholders being governed.

In order to tackle these issues, the RAINFOREST project has produced the **"Value-explicit Transformative and equitable Pathways in Food and Biomass Systems"** (VITAL-PATHS-FOOD). The VITAL-PATHS-FOOD present three positive and feasible visions of transformative change in global food and biomass systems towards nature-climate- and people-positive futures (Obura et al 2023). The latter terminology is primarily intended as defining target space in terms of outcomes, and is understood as a future state of the work in which the biodiversity, climate and socio-economic goals agreed under UN conventions (such as the Kunming-Montreal Global Biodiversity Framework, the Paris Agreement and the Sustainable Development

Goals) have been achieved (van Vuuren et al 2022). The three pathways each represent how a common justice and value-of-nature perspective could approach achieving the systems transformation needed to meet key multi-lateral goals. These pathways systematically explore how transformation could occur within six broad aspects of these food and biomass supply chains with multiple subthemes for each.

Table 1. VITAL-PATHS-FOOD abstracts

International Market Innovation
This pathway is built around an instrumental valuation of nature and a utilitarian account of justice. It depicts a world where the market drives the development of technologies and techniques which allow economic growth to be decoupled from biodiversity loss. There is a global liberalisation of trade relationships, and thriving biodiversity and carbon credit market, which allows for a global economic system to factor in its environmental externalities and adequately price nature. Precision farming techniques save space for an expansion of protected areas in high marginal utility regions and where they best provide society with valuable ecosystem services.
Global Sustainability Orchestration
This pathway balances instrumental and intrinsic valuations of nature and has a prioritarian approach to justice. In this future, robust global institutions are empowered to temper market-forces and orchestrate the food and biomass system towards sustainability, and balance the twin objectives of halting biodiversity loss while providing ecological space for development in the Global South. The market plays a comparatively reduced role as states and super-state entities coordinate production with global taxes and strategic nationalisations, and manage global resource redistribution to ensure that meeting environmental goals does not impede lifting the globally worst off out of poverty. Experts identify optimum areas for food and biomass production where there is ecological capacity to bear an intensification of production. The focus is on saving space for large interconnected and strongly protected areas where nature can flourish with little input from people.

Local Commons Stewardship
This pathway has an intrinsic and relational understanding of nature's value, where humans are seen as part of nature and foster close meaningful relationships with their bioregions. Power is increasingly devolved away from global institutions and communities take an increasingly larger role in governing themselves. Within these communities the economy shifts towards and increasingly "needs-based" model with and egalitarian approach to justice. On a global scale all communities understand themselves as being obliged to limit their consumption to what the planet can bear. Communities in the global north understand that they have a historical responsibility to reduce consumption to allow ecological space for development elsewhere. The global food and biomass system is increasingly shifted to labour intensive and low input organic production, with short supply chains as consumers increasingly switch to traditional food cultures and planetary health diet principles.

This report introduces the VITAL-PATHS-FOOD and the work the RAINFOREST has undertaken in developing them. It builds on Report D1.1 which reviews the foundational elements needed to produce new value-explicit pathways, and describes the overall approach. This report (D1.2) introduces the toolkit the RAINFOREST project has utilised to build and incorporate plural worldviews into the VITAL-PATHS-FOOD (Section 1: Overall Approach) and details the methodological approach taken in revising the draft pathways presented in D1.1 (Section 2: Summary of Methods) including reporting on our stakeholder engagement. Section 3 (Long Narrative Descriptions) gives detailed accounts of the three VITAL-PATHS-FOOD, exploring how key elements of the global food-and-biomass system are transformed to halt biodiversity loss, meet global climate targets, and progress of human development goals. Section 4 presents ongoing study into how the VITAL-PATHS-FOOD could be combined with target cross-scale translation methods to explore the results of different justice perspectives and burden-sharing approaches on key targets of the Kunming-Montréal Global Biodiversity Framework.

The VITAL-PATHS-FOOD contribute to filling an important gap in understanding global transformative change. While we believe these pathways present feasible,

coherent, and positive visions of future systems transformations towards nature-, climate- and people-positive futures, the aim of the VITAL-PATHS-FOOD is to galvanise wider engagement to understand these paths in greater detail. This report should be considered as a starting point for exploring these pathways further. Further quantification of the pathways is a key objective of the RAINFOREST project and will facilitate utilising Integrated Assessment Modelling to better understand the impacts and implications of these pathways, and to provide policymakers with actionable knowledge on needed to accelerate and facilitate transformations. Likewise with further stakeholder and expert academic engagement, the sectoral and cross-scale implications of these pathways could be better understood. The VITAL-PATHS-FOOD can form the basis for qualitative studies of environmental problems and form the basis for further visioning exercises of solutions to locationally or sectorial specific issues; and allow researchers and policymakers to identify key value and justice perspectives and triangulate actions to best utilise them as deep leverage points.

A - UPDATED PATHWAYS

§1 Overall scope

§1.1 Justice in Scenarios for the Biodiversity-Climate-Human Development Nexus

IPBES (2024) have argued that halting biodiversity loss requires "transformative change" "[global] reorganization [of] technological, economic and social factors". A similarly wide range of action is likely needed for global climate goals to be achieved (IPCC, 2022) and for the broader goals of the sustainable development agenda (TWI2050 2022). Such all-encompassing, globally distributed, reshaping of social and economic life is an inherently political task. It involves making normative decisions over who ought to bear the costs and reap the benefits that this reorganization, whose interests will be prioritized, and which principles will be used to make these decisions. These are salient normative questions which cannot be answered with additional empirical evidence alone, nor by simply "following the science". Instead, it will require engaging with axiological questions; questions of what is and what is not a just way to organize society; what elements ought to be preserved or discarded while undergoing transformative change?

Biodiversity, Climate, and Development policy especially sits within a nexus of political questions about how we distribute and utilize the land and natural resources of the Earth, and how we apportion the benefits of their use. It is clear that a key driver of biodiversity loss is habitat loss (IPBES, 2019), and particularly habitat loss in service of agricultural expansion (Corlett, 2020). Some two-fifth's of the planet's ice-free surface is now estimated to be under agricultural and livestock production (Machovina et al., 2015), or half of all "habitable land" (Ritchie & Roser, 2019) – effectively doubling since 1900. The effect has been what Rowland's describes as a "massive biomass reallocation program", as "natural" grasslands and forests, including their animal inhabitants, have been replaced with a comparable slender range of crops and domesticates (Rowlands, 2021). Any plausible strategy for halting biodiversity loss is therefore going to have to reckon with transformative change within this "food and biomass" system that governs the majority of the Planet's

surface.

Models and Scenarios have been identified as key tools for biodiversity science and policy (IPBES, 2016; Goudeseune et al, 2020). Scenarios – "[representations of] future trajectories of a system… plausible descriptions of how the future may unfold based on a set of assumptions about key drivers and their relationships" (IPBES, 2016) allow us to examine how "transformative change" towards achieving the goals of the KMBGF might be pursued if the interests or preferences of different groups of actors were prioritised. While existing scenario studies have explored transformative change within EU and the global food and biomass system (Leclere et al 2024), the ability of these scenarios to stimulate action for transformative change could be improved through a greater effort to incorporate justice preferences and values. Incorporating a greater range of equity/justice considerations, and diverse perspectives on these issues into scenario studies has been identified as key to developing the potential of scenarios to engage with deep leverage points (Chan et al., 2020; Obura et al., 2023; Zurek et al., 2021). While IPBES has made substantial efforts to develop systematic methods for incorporating diverse perspectives on the value of nature into environmental scenarios (IPBES, 2016; Periera et al, 2020; Duran et al, 2023), similar efforts should be made to systematically include diverse perspectives on justice into scenario narratives. What we aim to achieve with the pathways presented here (the VITAL-PATHs-Food) is to depict how the global food and biomass system could evolve under different visions of justice and the value of nature.

There are several reasons why a scenarios project ought to actively consider justice and values. Firstly, it is *justice for justice's* sake. It is prima-facie evident that the transformation of the world's economy raises questions of justice, and if mishandled carries a substantial risk of perpetuating the injustices which have accompanied historic conservation policies, including but certainly not limited to evictions and displacements which have accompanied the strict management of some protected biodiversity areas. By failing to acknowledge or actively consider justice within scenario design, policymakers may fail to recognise the justice implications of their actions. Moreover, where justice has not been incorporated explicitly into scenario design, particularly in climate scenarios, the outcomes have been adopting burden-sharing principles which have been argued to run contrary to justice (Dooley et al,

2019). On a more fundamental level, a just world all else being equal, is better than an unjust one – and we ought to promote justice for its own sake.

Secondly, it is increasingly evident that *justice is a leverage point* for effective environmental policymaking (IPBES 2022). Perceptions of policy fairness condition policy acceptability (Feola et al, 2019; Martin et al, 2020, Thaller et al, 2023) and therefore making effective biodiversity policy will require us to consider how different groups with different perspectives on justice will interpret the fairness of said policies. If values and justice preferences are not actively considered when designing scenarios there is a risk that the values and worldviews of stakeholders can instead become barriers to enacting transformative change, if the policy options identified are incompatible with the values and preferences of those they govern (Muradian & Pascual, 2018). By actively considering a plurality of justice preferences and nature values, scenarios can allow us to explore the possibilities for policy alignment and compromise between different groups of stakeholders holding different values and worldviews, and to allow policy pathways to be tailored to meeting stakeholder preferences.

In addition to these two reasons, we may also add that *justice is a feature of systems*. Beliefs about justice can be understood as "worldviews" (Stroebe et al 2015). Worldviews are underlying assumptions ontological assumptions about how the world is and how it *ought* to be. These beliefs about justice condition how we act, the policies we will tolerate, and the kinds of institutions we will permit to govern us. Scenarios which fail to consider these factors offer a diminished account of the variables which may influence the behaviour of the system as a whole; they offer an incomplete account of how the system in question operates.

Linked to this, *justice conditions scenario coherence*. A set of scenarios is made up of common "variables" – narrative elements that depict features of the system being modelled. Each scenario depicts a "variant" of the common variables. A theory of justice gives central organising principles which can explain why the variables which comprise a scenario are compatible with each other. Dooley et al (2019) point to studies of climate scenarios where the authors aim for value *neutrality* (as opposed to value-explicitness) leads to multiple competing sharing principles being present within the same scenario – i.e., creating scenario incoherence. However, the

problem is potentially deeper than this, as justice and worldviews provide explanatory accounts of why certain policies ought to be pursued and not others. A scenario might be incoherent if for each of the variables/narrative elements it contains there is not a unified worldview which can explain why each variable evolves in the way it does. For instance, a scenario guided by a single coherent worldview might appear incoherent if it contained a laissez-faire trade policy, but an energy policy built around nationalisation of the power industry. Being explicit about the principles of justice which underly the scenario, and not leaving it to the inference of the reader, can ensure that the sum of the variables included are internally non-contradictory.

Incorporating justice into scenario design in this way requires designers to take a systematic approach. There are two possible ways to approach justice and values within a scenario project. *Normative* approaches begin with a preconceived idea of what justice entails and seek to contrast how a scenario organised according to these principles may contrast to (unjust) scenarios where justice is not applied. The challenge of taking a normative approach to justice is that justice is an *essentially contested concept*. There are and will likely remain substantial competing interpretations and beliefs amongst people about what "justice" means and what policies are compatible with justice (Oates, L & Verveld, L, 2024). Given that perceptions of justice condition policy acceptability (Martinet al., 2020; Thaller et al., 2023; Bergquist et al.,2022), there is a risk that a normative approach to modelling justice might track the justice preferences of the researchers but diverge from the preferences of (segments of) the public.

In RAINFOREST however we adopt a non-normative approach. A *non-normative* approach by contrast acknowledges that there are plural plausible[1] accounts of justice; and explores the implications of them on the system being modelled by treating them as a variable affecting the system. This approach allows us to examine how transformative change could occur if different justice principles were used to govern the transition. Crucially though this is not the same as purporting to be

[1] It is beyond the scope of this deliverable to offer a substantive account of what makes a theory of justice "plausible". We rely on the taxonomy of significant or influential accounts of justice provided by the AJUST Framework.

"value-neutral" (Dooley et al, 2019). Rather, the pathways presented in this report are explicit about the values of nature and the perspective on justice which they represent, however they are non-evaluative. Our aim with these pathways is to present plausible visions of how a "world living in harmony with nature" might be accomplished if competing worldviews achieved their aims.

§1.2 Scope of Pathways

Following the framework provided by AJUST, we identified the "Context" of our pathways as "the global food and biomass system". On a temporal scale our pathways imagine a future where the KMGBF vision of "A World Living in Harmony with Nature" is achieved by the target date of 2050. The "spatial scope" of the pathways is therefore also global. This is owing to the fact that the food and biomass system is a global one: food and biomass value chains are frequently globe-spanning and highly interlinked through the sinews of trade which relocate biomass from the place where it is produced to the place where it is consumed. Processes which degrade biodiversity in the tropics, such as deforestation to clear land for new agriculture, are often driven by the demand for imported agricultural products in the global north – e.g., in the case of soy-fed beef. Likewise, even where value-chains are primarily local, within a globally connected world local change to food-and-biomass systems can stimulate distant effects through altering prices or displacing production elsewhere.

Biodiversity is a globally variable and locally specific phenomenon. Globally biodiversity is not evenly distributed, and in terms of species diversity biodiversity is highly correlated with global poverty in the tropics. Protected areas for biodiversity presentation necessarily are sited where the species they aim to protect are present, but protected areas place limits on the kinds of economic activity which may occur within them. That economic activity can either be lost, or else displaced to some other site; therefore, the expansion of protected areas in one region can therefore increase the demand for land elsewhere. Likewise, as biodiversity and poverty are highly spatially correlated (Hernandez-Morcillo et al, 2010), there are risks that those who assume the burdens of protecting biodiversity and the burdens caused by its loss, are those who are least able to bear them. Without adopting any particular normative stance, the confluence of these facts indicates that protecting

biodiversity has the potential to exacerbate global inequalities.

However, while examining global dynamics in our pathways we focus in detail on how the European Union operates within this global context. This aligns with the focus of the case study research undertaken within RAINFOREST and allows these to inform the dynamics of the pathways. Likewise, the availability of policy information from the European context allows us to go into greater detail. A more in-depth review/taxonomy of interventions may be found in RAINFOREST Deliverable D1.1 (Leclere et al 2024).

The second context element of the pathways is the "target space" that they aim for. These pathways all aim at a future world in which the biodiversity, climate and socio-economic goals agreed under UN conventions are achieved. They each present a vision of "a world living in harmony with nature" (KMGBF), a world where "warming kept well under 2°C" (Paris Agreement) and much or all of the Sustainable Development Goals have been achieved (van Vuuren et al 2022). The objective is to explore how different groups each with different substantive understandings of justice and the way to live harmoniously with nature might visualise such a world.

§2 Summary of methods

§2.1 Overall Approach

The approach to scenario development employed within the RAINFOREST project is based on the "Story and Simulation" approach (Alcamo, 2001). Story and Simulation is a method for scenario generation which begins with an initial expert-led process that constructs the basis of the scenario storylines, drawing from literature review and original research and knowledge of the subject area. These initial drafts are then improved and co-developed through an iterative process with stakeholders to better understand processes within the storylines and to broaden the perspective on the feasibility of the pathways. In addition to stakeholder iterative process, further refinement of the storyline can be gained through quantification and modelling.

IPBES also give methodological advice on the preparation of scenarios and modelling efforts (IPBES 2016). It is noted that stakeholder engagement processes do not have a single acceptable format and may vary considerably in the method, extent, and intensity to which stakeholders feedback on scenarios. Throughout this report, we

detail the efforts made to engage stakeholders in feeding back on the draft RAINFOREST pathways published in deliverable D1.1. The development of the initial pathways also contained elements of co-production and likewise it should be noted that the two sets of pathways which formed the seeds of the VITAL-PATHS-FOOD (The New Narratives for Nature (Duran et al 2022) & The Sustainable Development Pathways (Kriegler et al 2022)) were produced following an extensive stakeholder engagement process. By building from this work, we were able to ensure that stakeholder involvement was involved at all points of the generation of the VITAL-PATHS-FOOD, and ensure that our scenarios have linkages and easy comparability to existing co-produced scenario frameworks.

§2.2 Tools for Developing Value & Justice Explicit Pathways

We utilised two tools for ensuring that our approach to incorporating justice and the value of nature explicitly into our pathways was done in a systematic manner: The AJUST Framework and the Nature Futures Framework. In this section we detail how these tools were utilised throughout the initial development of the RAINFOREST draft pathways (RAINFOREST Deliverable D1.1 Leclère et al, 2024) and throughout the process of revision which led to the updated pathways VITAL-Paths presented here.

§1.2.1 AJUST Framework

For the development of the VITAL-PATHS, we utilised a non-normative framework – *The Applied Justice Taxonomy and Assessment Framework* (AJUST) -to identify justice considerations, to provide consistent and explicit terminology, and to detail competing theories of justice to act as variables in the scenario pathways. AJUST gives five stages for conducting a justice analysis: *Justice Context, Justice Scope [Spatial, Temporal, Entity], Forms of Justice, Metrics of Justice,* and *Patterns of Justice*. The "Context" is the subject of the analysis – in our case the *Food and Biomass System*. "Scope" is where the analysis is bounded: within a particular time period (up to 2050), and within a particular spatial extent (globally, with a special focus on the European Union). "Entity scope" refers to the kinds of entities (e.g., humans, non-human animals, "nature" itself) to which justice is thought to apply. Within our pathways, the entity scope is a variable which changes between scenarios according to the "valuation of nature" being depicted.

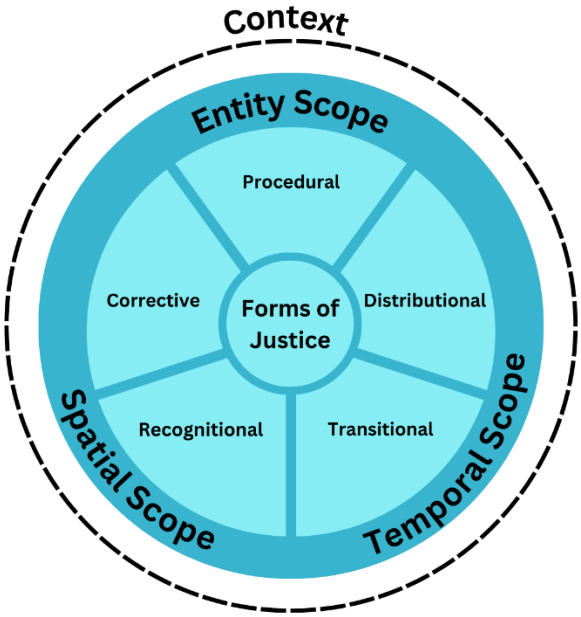


Figure 1. The AJUST Framework Graphic. Source: Hanger-Kopp et al, 2024

Justice is understood to be a multi-dimensional concept. The AJUST Framework breaks down justice into five "forms": *distributional; procedural; recognitional; corrective; and transitional*. In the VITAL-PATHS-FOOD Pathways we treat the first three of these as scenario variables, and explore the way changes in beliefs about distributional, procedural, and recognitional justice alter the way transformative change in the food and biomass value system is enacted.

"Distributional Justice" refers to the fairness of distributions i.e., how are the benefits and burdens which a system produces distributed amongst its members? "Metrics" and "Patterns" of Justice are particularly relevant for analysing distributional justice. In order to consider distributional justice you need to identify what is being distributed. These are the "metrics" of justice and can be anything within a system that might be beneficial or burdensome to the actors who comprise it. Within the development of the VITAL-PATHS-FOOD the "metrics" we consider are incorporated into the variables we discuss – for instance, when considering how protected areas (metric) are distributed between regions. A "pattern" of justice is a particular normative account or theory of the ideal distribution of any given metric. A pattern gives a reasoned explanation, justification, or formula for identifying what a fair distribution should look like. The AJUST Framework gives a taxonomic account

of key distributional patterns which have been prominent within the philosophical literature on distribution justice. Treating "distributional justice" as a variable across the pathways allows us to select a distinctive "pattern" of justice for each scenario; and from the descriptions of the patterns given in the AJUST framework use this as an organising principle to explain how and why the variables in each pathway are organised in distinct way from each other. This allows our pathways to be explicit about the particular understanding of justice they employ, and coherent by allowing that principle to coordinate how each of the narrative elements of the scenario relate to each other.

It has been previously claimed that distributional justice is "the only area of justice theory… clearly relevant to the environment" (Vincent 1998). However, we now recognise that all aspect of justice are relevant when analysing the complex interrelationships of food and biomass systems. "Procedural justice" (the fairness of decision-making and distributive- processes) and "Recognitional justice" (the fair and appropriate apportionment of dignity and recognition between individuals and groups within a society) was also identified as a key variable to include in the pathways as a major element of the pathways is the kinds of governance, institutions, and social interventions being utilised in each. Rather than ascribing a particular "pattern" or "theory" of recognitional or procedural justice to each pathway, the pathways are distinguished by the comparative level of importance given to this form of justice as compared to simply ensuring that distributional outcomes match the preferred pattern (D1.1 p. 94).

Procedural justice is conceptualised as relating to the level of involvement/says individuals can expect in a decision-making procedure, how far removed they are from the levers of power, and the degree of coercive authority they will tolerate from their governing institutions. Levels of citizen participation are often conceived of on a spectrum of low- or non- participation, top-down control, or active manipulation, to increasing levels of decision-making authority and citizen involvement (E.g., Arnstien, 2019). However, these are often explicitly normative frameworks that see increasing levels of citizen participation as inherently beneficial. While in this study we do utilise a spectrum to map our pathways on a scale of how much participatory involvement they contain, crucially this is not understood as a spectrum of how procedurally just/unjust the pathway is but instead

conceptualises different substantive visions of what a fair-processes looks like. There is increasing evidence that increasing levels of participation does not always entail a greater perceptual sense of the process' fairness. Lawrence notes that environmental procedural justice is sometimes understood as a dichotomy between "instrumental" and "transformative" approaches but argues this is an unhelpful way to conceive of the different forms participatory approaches can have (Lawrence, 2008). Epstein argues that the traditional procedural dichotomy of "participation" to "enforcement" used in conservation studies fails to capture the substantive reasons people have for accepting and following rules and regulations (Epstein, 2017). Moreover, in what has been termed the "legitimation paradox", Fudge (2018) demonstrates that in marine conservation efforts to widen and deepen participation in rule-making has counter-intuitively been related to low-levels of trust and legitimacy.

We utilise this participatory-enforcement dichotomy to organise our pathways, but do not take a normative stance on whether highly participatory processes or top-down enforcement processes are morally preferable to each other – rather we conceive of them as representing competing visions of what fair procedures could look like. Pathways which give a "high" importance to procedures might focus on designing procedures and governing institutions towards ensuring that all-affected are included in decision making with full expectation that their preferences will be considered in the process. Incorporating more people into decision-making and in deeper ways, e.g., through additional rounds of consultation or requiring greater degrees of consensus comes with a cost to the speed and decisiveness with which an institution can act. Pathways on the "low" end of the spectrum might view the design of procedures as secondary to the ability of the decision-making organs to produce distributionally fair outcomes. These pathways may contain institutions which are to a greater deal expert-led, with top-down governance, and where authorities are given greater power to act and with fewer checks in order to streamline the process.

Likewise, the pathways are differentiated on an axis of "wide-narrow" recognitional justice. Recognitional justice within the pathways is conceptualised as how explicitly institutions seek to reflect and consider the culture, values, and situations of affected parties (Whyte, 2011). As with procedural justice, this is not envisioned on a spectrum of just to unjust but as pathways which disagree over the substance of

what level of explicit recognition is required by justice. As justice relates to *enforceable* obligations (Buchanan, 1987; Miller, 2003) questions of recognitional justice in this regard are about whether parties have a claim on states, governing institutions, or humanity as a whole to ensure that their culture/identity is in some way recognised. A pathway with a narrow account might focus on ensuring a liberal conception of "equality before the law" that does not recognise differences between parties, whereas a wide account might have provisions within governing institutions or laws which give explicit special consideration or affirmative action to presently sub-altern groups or culture, for instance, by giving devolved authority to a minority culture, or considering historic responsibility/reparations to marginalised or exploited regions/peoples.

§1.2.2 The Nature Futures Framework

In addition to using the AJUST framework to identify forms of justice to structure the scenario pathways around, the VITAL-PATHS pathways also trade-off different perspectives on the value of nature. As with "Justice" incorporating competing perspectives on the value of nature also requires a systematic approach. Values (of nature) are understood by IPBES to be a "deep leverage point" to act on when making transformative change to a system. Within this context, IPBES developed the Nature Futures Framework (NFF) as a means of conceptualizing and systematizing the inclusion of different perspectives of the value of nature into scenario development and research design.

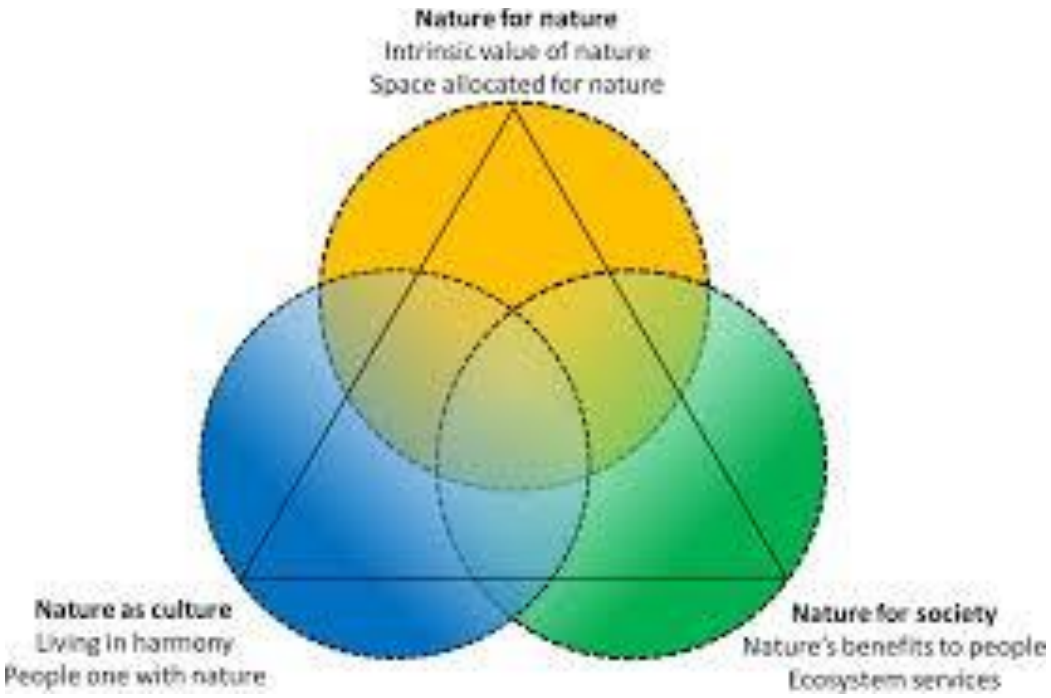


Figure 2. The Nature Futures Framework. Source: Periera et al, 2022a

Like "Justice" the valuation of nature which predominates in a scenario narrative offers a means of organizing the narrative elements within a scenario and ensuring the internal consistency of the scenarios themselves by providing an explanatory factor/underlying logic for why each of the narrative elements have been incorporated into each pathway in the way that they have.

The Nature Futures Framework identifies three ways in which people value nature, each of which gives a motivation for why nature ought to be protected. "Nature for Society" (NfS) views believe nature's value is the instrumental value it has for people. These views believe that nature-protection ought to be pursued as a means of safeguarding the ability of people/society to reap the instrumental benefits of nature. "Nature for Nature" (NfN) sees nature as having intrinsic value in addition to the instrumental benefits it brings. "Nature as Culture" perspectives reject the instrumental-intrinsic dichotomy and instead focus on the value of relationships with nature; perhaps seeing themselves as inseparable from and an intrinsic part of the natural world.

§2.3 Development of the D1.1 Pathway Drafts

The pathway narratives presented in this report are a refinement of the draft RAINFOREST pathways that were presented in D1.1 (D1.1 Pathways). This section gives an overview of the methods utilised in creating the D1.1 pathways which formed the basis of the VITAL-PATHS-FOOD. The D1.1 Pathways were constructed through an iterative process between expert-led qualitative storyline design, feedback from stakeholders and quantification with models. Three concrete steps formed the basis of the D1.1 pathways:

- A new conceptual framework for incorporating plural (environmental) justice considerations into scenario design [AJUST] (Hanger-Kopp et al, 2024)
- A combination of two existing sets of value-explicit scenario narratives – the "New Narratives for Nature" (Duran et al 2022) and the "Sustainable Development Pathways" (Kriegler et al 2022) through a mapping-exercise.
- A review of transformative change "interventions", structured around a value-chain taxonomic model which distinguishes: production; intermediate; consumption; and systemic interventions (Leclère et al 2024). These form the "narrative-elements/variables" which would make up the D1.1 pathway narratives.

Short descriptions of the D1.1 Pathways may be found in the following Table 1. The full narratives appear in RAINFOREST D1.1 Section 5.4 (Leclère et al 2024).

Table 2. Short Pathway Narratives from D1.1. Source: Leclère et al, 2024.

Global Green Innovation
In this world, liberal, functional, and global world views become prevalent. Societies embrace innovation, efficiency, global action (driven by private sector actors supported by state actors) and equal rights (in the sense of ownership, but also light touch welfare state) as key elements to depart from current unsustainable trends and drive the transition towards sustainable development. A highly connected world that shares knowledge and technology to maximize

efficient, intensive and sustainable utilization of natural resources while ensuring maintenance of the key ecosystem functions that support nature's contributions to people. Demand might evolve towards innovative sustainable products. Plurality of voices is assumed to be enabled via market mediation of individual choices, and there is moderate emphasis on reducing inequalities and including considerations from vulnerable and marginalized people. Efforts towards global goals are shared based on grandfathering, cost-effectiveness and (potentially) progressivity.
Based on: NN-NS Nature Futures Pathway and EI Sustainable Development Pathway
Needs Based and Nature Connected Local Stewardship
This world develops towards community- oriented world views, emphasizing solidarity and wellbeing. Societies emphasize regional diversity, and move towards a post-growth economy model and rely on equitable sharing of resources and economic wealth to ensure sustainable development. Biological and cultural diversity are co-conserved and co-managed across a wide range of interconnected bio-cultural systems. Land is used extensively with minimal areas devoid of human activity and a strong social connection and geographical proximity between producers and consumers, while the focus on a needs-based society and lifestyle changes supports a reduced footprint on resources. A large plurality of voices is ensured through high reliance on social networks and polycentric decision-making, reducing inequalities is seen as a goal per se and a key lever for achieving other global goals. There is a high recognition of the needs of vulnerable local communities. Efforts towards global goals are shared based on need, capacity, and subsistence.
Based on NN-NC Nature Futures Pathway and RC Sustainable Development Pathway
Global Stewardship Towards Co-Existence
In this world, global norms and the perception of global citizenship become prevalent. States and global institutions orchestrate the transition towards sustainable development, including an increased focus on human services and decreased emphasis on material consumption. People protect the self-regulating capacity of the biosphere as biodiversity and natural processes provide the

resilience that enables humanity to stay within planetary boundaries. People also respect and value all life on Earth intrinsically and, therefore, set aside areas to be undisturbed with low to no human intervention. In addition to sparing space for nature, remaining areas are used with medium intensity and consumption footprint is reduced by a mix of regulation and consumer awareness. Expert-driven decision-making and multilateralism are seen as more efficient than ensuring a plurality of voices in decision-making, poverty and hunger alleviation are pursued as goals per se. There is a medium of recognition of the needs of vulnerable local communities. Efforts towards global goals are shared based on capacity (more or less same as egalitarian) and responsibility.
Based on NN-NS Nature Futures Pathway and MC Sustainable Development Pathway

These pathway drafts were created through an iterative approach of feedback and revision following the story-and-simulation approach laid out by Alcamo et al (2008). This process begins with a process of expert story-line design to agree on the scope and components of the scenario project and to produce draft narratives. These narratives are then introduced to stakeholders for review, to assess alignment, and prompt revisions. Further feedback is gathered through initial quantification and review of the initial pathways through quantification and modelling efforts to understand the likely impacts of the pathways. These streams of feedback are then incorporated into a final drafting of the narratives – which are presented in this report. The initial crafting of the narratives involved a comparison of two value-explicit scenario sets, “the New Narratives for Nature” and the “Sustainable Development Pathways”. These were identified as matching the intended scope of the D1.1 pathways by presenting global scale scenarios which incorporated narrative themes of environmental management and human development.

§2.2.1 New Narratives for Nature

The Nature Futures Framework provides a framework for developing value-explicit scenarios but are not scenario narratives themselves. However, Duran et al (2023)

developed a set of six "illustrative narratives" which provide archetypal global scale "skeleton" narratives of the value positions at each of the three extremes of the NFF triad, plus "balancing" positions (NfN-NfS; NfN-NaC; NaC-NfS) at the interstitial points between them. Each of these scenarios trade-off on twenty-two different variables identified as being important components of socio-ecological systems (See Table 2) including: governance, societal functions, natural resource management, habitat and biodiversity, and societal organization.

While the New Narratives of Nature succeed is depicting (skeleton) narratives which are explicit about the "value of nature" being presented in each scenario, these could not on their own provide the basis for the RAINFOREST narratives, which in addition to being explicit and systematic in the way they conceptualize nature also needed to be systematic and explicit about justice preferences. While many of the variables which are included in the New Narratives for Nature make references to justice-relevant issues (e.g., governance) the pathways are not explicitly arranged according to justice preferences.

Table 3. Variables within the New Narrative for Nature

New Narratives for Nature	
Grouping	**Variable**
Societies' Governance	Economy
	Government
	Cities
	Communities
Societies' Functioning	Infrastructure
	Energy
	Transport
	Water
Natural Resource Management	Food
	Diet
	Agriculture
	Fisheries
	Aquaculture

	Land Management
	Well-Being
Habitat and Biodiversity	Megafauna
	Oceans
	Biodiversity Use
Societies' Organisation	Trade
	Law-Rights
	Education
	Policy

§2.2.2 The Sustainable Development Pathways

The Sustainable Development Pathways (SDPs) were developed within the SHAPE project to explore value-explicit pathways to a world where the goals of the sustainable development agenda are achieved. The SDPs contain five narrative scenarios representing how different value-perspectives would seek to reach the target space (Van Vuuren et al, 2022; Weindl et al, 2024) of each of the 17 Sustainable Development Goals (Kriegler et al, 2022). "Economy Driven Innovation" (EI) presents a liberal and globalised world, focussed on market efficiency and innovation to drive sustainable development; "Resilient Communities" (RC) is community oriented, emphasising a post-growth pathway with a regionalisation of political authority; "Managing the global commons" (MC) is a global, politically cosmopolitan, pathway where supernational entities are given increased scope and authority to manage the global economy towards sustainability; "Local Solutions" sees states exerting regional autonomy and pursuing regionally specific approaches to provisioning within environmental boundaries; "Green and Social Market Transition" (GS) is a globally oriented pathway where non-state actors, states, and global institutes, coordinate a "well regulated" economy. The pathways trade off on 12 thematic areas of which each has three possible variants (See Table 2).

The narratives provided by the SDPs provided a useful compliment to the New Narratives for Nature for drafting the initial RAINFOREST pathways by providing more detailed accounts of pathways for sustainable human development, while sharing a

common global scale and mid-century perspective. While the SDPs do not explicitly focus on the different ways in which nature can be valued, this element of the scenarios could be imported by mapping them to the New Narratives.

Table 4. Variables in the Sustainable Development Pathways.

Sustainable Development Pathways	
Variable	**Variants**
Societal Governance	Economy Driven
	Society Driven
	Politically Driven
Global Governance	Convergent Liberal
	Divergent Glocality
	Convergent Cosmopolitan
Economic Paradigm	Innovation Driven
	Solidarity Driven
	Service Driven
Future of Work and Technology	Symbiosis
	Deceleration
	Homecoming
Urbanisation	Tech Cities
	Distributed Cities
	Green Cities
Mobility	Sci-Fi Mobility
	Sustainable Lifestyles
	Green Mobility
Sustainable Production & Consumption	High Tech Future
	Caring for the World
	Sharing Global Commons
Land & Food	Sparing
	Caring
	Sharing
Energy	Market Supply
	Energy Communities

	Flexible Electrification
Water	Water Innovation
	Low Tech
	Regional Water Partnership
Health and Education	Market Driven Innovation
	Holistic Approach
	Global Programs
Nature (Biodiversity & Ecosystems)	Symbiosis
	Sufficiency and Co-Existence
	Global Efficient Safeguarding

§2.2.3 Combining the New Narratives and the SDGs

A combination of the variables present in both the New Narratives for Nature and the Sustainable Development Pathways formed the basis for the original Draft pathways. A mapping exercise was undertaken to explore where the scenarios from both sets most closely overlapped.

Mapping exercises with the NFF are a standard exercise within the community of practice and provide a way of examining and comparing the value of nature present within a sample. However, despite ongoing revisions of the NFF there is as yet little methodological guidance on how mapping exercises should be undertaken. Two sources of methodological guidance exist but neither offers specific advice how to conduct the crucial act of plotting to the NFF during a mapping exercise. The primary source of methodological guidance is a working document [the Methodological Assessment Report] published by the Task Force on Scenarios and Models and reviewed by the Multidisciplinary Expert Panel and Bureau 2023 (Lunquist et al, 2023). The authors write that "[the guidance] is not intended to be prescriptive… rather the [guidance] is flexible to allow its application to a variety of contexts." But they do not offer guidance on how to plot positions onto the NFF, effectively allowing practitioners to develop their own methods for doing so within their research projects. Secondarily in 2023 members of the IPBES Expert Group and the Task Force on Scenarios and Models under Prof. G. Peterson and G. Penrose created a website (https://cube-tetra-3ecl.squarespace.com/) for users of the NFF to act

as the locus for a community of practice to develop around. This website contains a section on methodological guidance for using the NFF, and likewise preferences that it is neither prescriptive nor highly specific. But as with the Methodological Assessment Report, the authors do not give guidance on how to locate where a scenario should be plotted onto the NFF. The mapping exercise undertaken in the drafting of the D1.1 pathways followed established practice of using collaborative expert deliberation to determine where each of the SDPs would be placed.

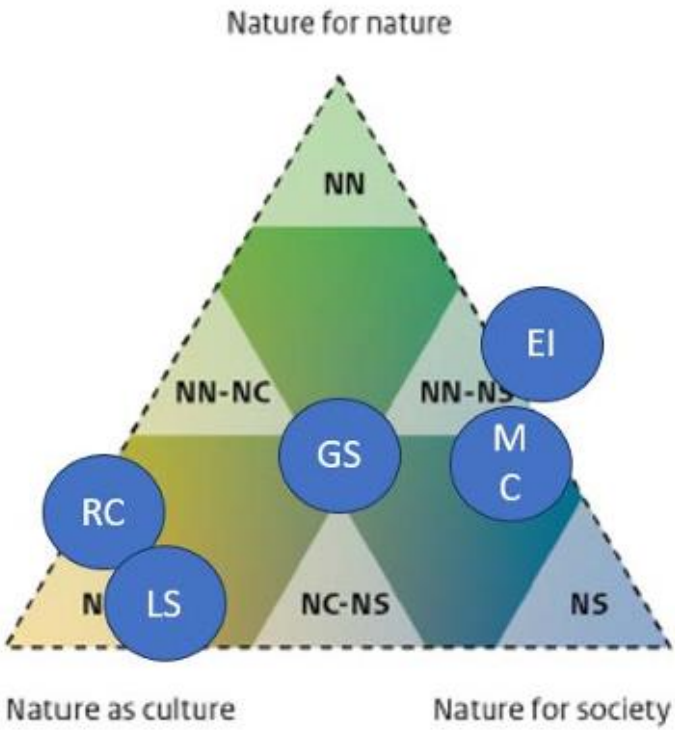


Figure 3. Mapping of SDG Pathways to the New Narratives for Nature/Nature Futures Framework. Source: Leclère et al, 2024. The blue circles represent the five SDG pathways – Economy Driven Innovation (EI), Resilient Communities (RC), Managing the Global Commons (MC), Local Solutions (LS), Green and Social Market Transition (GS) - which are superimposed onto the Nature Futures Framework triangle where the extremities represent Nature for Society (NS), Nature as Culture (NC), and Nature for Nature (NN) valuations, plus balanced scenarios between them.

Mapping onto the NFF allows us to make explicit how we conceptualise the nature-value present in each pathway. An additional mapping of the SDPs arranged the

scenarios along three axes depicting the three forms of justice chosen as variables for the RAINFOREST pathways: distributive, procedural, and recognitional. Crucially, these axes do not depict gradients of "Just-Unjust" as each of the RAINFOREST pathways are intended to depict a future according to some theory of justice. Rather, the gradients reflected "High-Low Plurality of Voices" (Procedural Justice), "Egalitarian – Non-Egalitarian distributive preference" (Distributive Justice), and "Explicit – Passive reflection on marginalised/vulnerable individuals/groups" (Recognitional Justice). These factors are not intended as stand-ins for substantive descriptions of the accounts of justice present in the SDPs, but rather offer a simple heuristic/proxy to allow a comparison of the pathways.

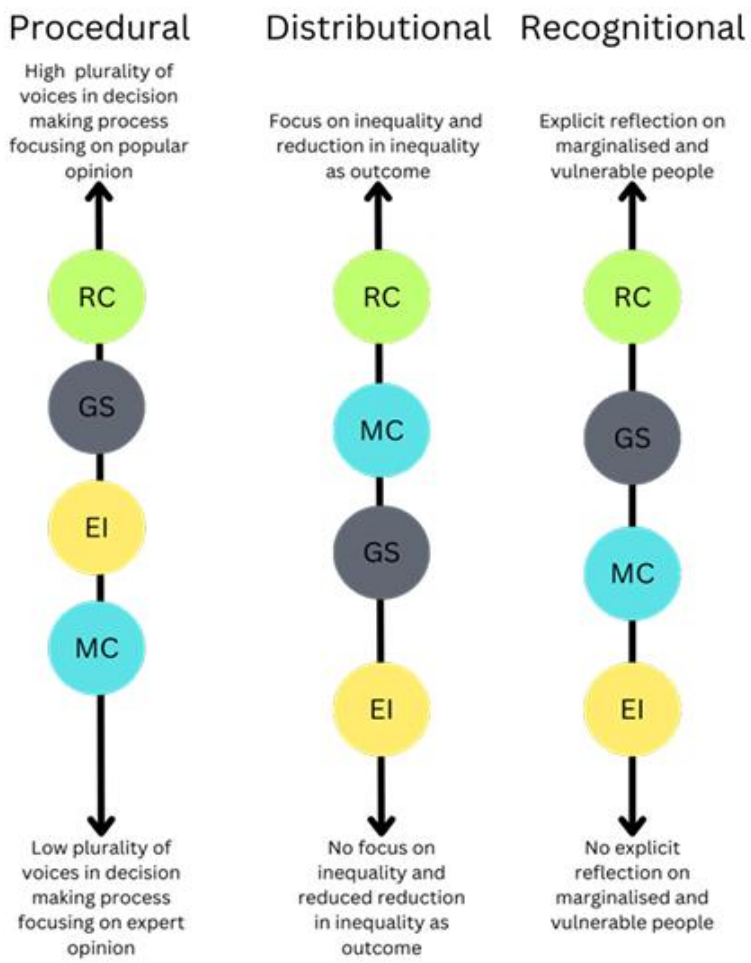


Figure 4. Alignment of SDP Pathways (Economy Driven Innovation (EI), Resilient Communities (RC), Managing the Global Commons (MC), Local Solutions (LS), Green and Social Market Transition (GS)) Across Proxies for 3 Forms of Justice. Source: Leclère et al, 2024

§2.4 Variables and Narrative Elements

In the VITAL-PATHS-FOOD Pathways each pathway contains an account of its value of nature, and its account of distributive, procedural, and recognitional justice. These variables provide top level guidance for shaping the how the narrative elements are included within each pathway and ensuring the for every variable included in the pathways the variant included is coherently aligned.

Table 5. "Justice Preferences" and "Valuation of Nature" Variables and Possible Variants in the VITAL-PATHS-FOOD

Overarching Variable	Possible Variations
Valuation of Nature From Nature Futures Framework & Duran et al, 2023 Illustrative Narratives	Nature for Nature (NfN)
	Nature for Society (NfS)
	Nature as Culture (NaC)
	Balancing NfN-NfS
	Balancing NfN-NaC
	Balancing NfS-NaC
Distributional Justice From AJUST Framework	Egalitarian
	Prioritarian
	Utilitarian
	Limitarian
	Sufficientarian
Procedural Justice From AJUST Framework	Highly Participatory
	Balanced Participation
	Expert led
Recognitional Justice From AJUST Framework	Wide Recognition
	Medium Recognition
	Narrow Recognition

D1.1 ended with a call for improving the pathway drafts though a widening of the themes considered; and a deepening of the detail that each of the pathways explored. Our approach in revising the pathways has predominately focused on the latter approach – deepening the factors considered in each theme through a more

in-depth consideration of the sub-variables included in each pathway. The selection of these variables included in each pathway was based on expert-led deliberation within the project team and based on expert-feedback received in the review process, and based on an understanding of factors of the food and biomass system which would be pertinent to understanding transformative change interventions.

For the draft RAINFOREST pathways, we determined the variables/narrative elements from a multi-facetted process. Firstly, the Draft Pathways were developed through a process of combining two sets of value-explicit pathways – the "New Narratives for Nature" (Duran et al, 2023) and the "Sustainable Development Pathways" (SDPs). It was found that the "themes" of the pathways (the variables) had a strong degree of compatibility, albeit with the New Narrative's for Nature providing more detail on socio-ecological factors, while the SDPs provided more detail on economic, social, and technological factors.

In the updated pathways each scenario compares how transformative change would develop across seven different components of the food and biomass system. These system components were additionally broken down into sub-variables which were systematically incorporated into each of the scenario pathways. Table 3 breaks down the seven components, their associated sub-variables, and gives an indication of the question each pathway narrative answers. D1.1 suggested that a route for improving the pathways would be "inclusion of key elements for equity", to allow the pathways to be further differentiated according to their respective perspectives on justice. The AJUST framework was employed to identify variables that were likely to be pertinent to understanding the justice of the system; such as variables where there are already widely reported questions of (in)justice, or where changes to the variable were likely to substantially impact the lives of some people.

Table 6. Narrative Elements/Variables included in D1.2 Pathways

System Component Variables/ Themes	Sub-Variants/Narrative Elements	Indicative Questions/Description
Agriculture	Restoration Type	How is on farm restoration achieved?
	Sustainability Concept	Extensive or Intensive Agricultural Systems?
	Livestock	What is the quantity and relative importance of livestock and associated feedstocks in global agricultural balance?

	Crop Types	How are crop types determined?
	Yields	Increasing or Decreasing and Where?
	Mechanisation/Labour	How does mechanisation and labour develop?
	Landscape Scale	How are agricultural and natural elements distributed on a landscape scale?
	EU	What is the agricultural situation in Europe? Where does Europe source its agricultural products from?
Forestry	Restoration Type	How and where does forest restoration occur?
	Forest Typology & Naturalness	What kinds of forests are prioritised; what is the attitude to promoting "natural" vs managed and non-native forests?
	Landscape Scale	What principles determine how forests are located on a landscape scale?
	Global Distribution	What principles determine the global distribution of forests? Where is forestry located, how does this change from today?
	EU	What is the forestry situation in Europe? Where does Europe source its forestry products from?
Trade and Intermediary Processes	Food Loss & Waste. KMGBF Target 16	How are KMGBF targets on reducing food loss and waste tackled? What approach is used?
	Sustainability Standards	How are sustainability standards set? What enforcement mechanisms are used? What is the geographic distribution
	Distribution Networks	How are supply chains structured?
	Global Trade	What principles govern global trade? How does global trade differ from the present?
	Added Value & Differentiation	How do intermediary supply chain actors add value and differentiate products?
Government & Institutions	Primary Governance Level	At what level (global-local) is the primary locus of political power located? At what scale does governance take place?
	Role in Supporting Transition	How to states and government institutions see their role in supporting transformative change? What is the legitimate extent of their remit?
	Relationship with Markets	How to governments see their relationships with the markets? Are they interventionist or laissez-faire?
	Democracy and Procedural Justice	What kinds of democratic institutions make decisions about the transition? What is the role of experts in governance? How much

		say can ordinary citizens expect in decision making?
	Inclusion and Recognitional Justice	Who gets a say in decision making processes? What grades of differentiation do states recognise between citizens? What level of effort is made to include and recognise sub-altern groups?
	EU	How has the governance of the EU change? What dynamics exist between its members? What kind of authority does the EU parliament have to coerce its members?
Bioenergy and Carbon Capture	Scale of BECCS	What is the relative need for BECCS in this pathway?
	Location of BioEnergy Crops	Where is bioenergy crop production located, at both a global and a landscape scale? What principles determine its location?
	Other Negative Emissions Methods?	What other methods of (non-forestry) carbon capture are being employed in this pathway?
	Carbon Offsetting	Is carbon offsetting permitted in this pathway; and if so on what scale? How is it regulated?
Protected Areas	KMGBF Target 3 30% Protected Areas	How is the KMBGF Target of 30% terrestrial protected areas distributed. What principle determines the distribution?
	IUCN Protected Area Taxonomy	How strict is the protection of protected areas? How would they fall on the IUCN Taxonomy?
	Single Large or Several Small: SLOSS	What is the preference for protected area connectivity? Where does the scenario fall on the SLOSS debate?
	Compensation Baselines	How is compensation for lands lost to new protected areas determined? What baseline is used?
	Exclusion	How are exclusion risks provoked by an expansion of PAs handled? What is the role of IPLC in governing PAs
	Landscape Scale	How are protected areas distributed across a landscape scale?
	Global Distribution	How are protected areas distributed globally? How is Target 4 shared between nations? What principles determine the global distribution of Pas?
	EU	What is the situation of protected areas in the EU? How does the EU act regarding protected areas abroad? How does it view its responsibilities?
Sustainable	Relative Consumption	What is the relative quantity of global

Consumption	Levels	resource consumption in this pathway? How is consumption distributed globally? What principle explains this distribution?
	Mitigation Hierarchy	How is sustainable consumption achieved? What aspects of the mitigation hierarchy (substitution/reduction/prevention) are prioritised?
	Nutrient Loss: KMBGF Target 7a	How is KMBGF Target 7 shared between nations? What kinds of measures are used to address nutrient loss?
	Fertiliser use	Where and according to what principle is global fertiliser use allocated?
	Pesticides and Hazardous Chemicals: KMBGF 7b	What is the approach taken to reducing the use of pesticides and hazardous chemicals? What principle determines where the usage is allocated?
	Sustainable Choices	What dynamics drive demand-side sustainable choice making? What is the role of government in promoting sustainable consumption choices?

An identified aim for the pathway revisions in D1.1 was improving the contrast of the pathways, and this is reflected in the selection of variables. As the aim of the VITAL-PATHS-FOOD pathways is to depict futures where the KMGBF vision of "a world living in harmony with nature" is achieved, variables pertinent to the targets of the KMGBF (particularly targets 4, 7, and 16) were also selected. Additional insight into the selection of variables was gathered from the RAINFOREST case-studies which helped us understand key dynamics of where transformative change interventions would operate. Likewise, we received feedback on the draft pathways through a series of feedback sessions with stakeholders and academic and policy experts who guided us on the variables to include.

§2.5 Revision of the Pathway Drafts

The D1.1 Pathways narratives were "very preliminary" versions of the final versions presented here. D1.1 (Leclère et al 2024 p.77) outlines three objectives needed to revise and improve them:

A. Refining of the "Intervention" and "Feasibility" dimensions based on feedback from RAINFOREST Work Packages 3 & 4 (Transformative Change Case Studies)
B. Incorporation of feedback from project partners, the stakeholder group, the advisory board, and the broader community.
C. Inclusion of considerations from: Early Stages of Target Downscaling (WP1); Modelling Toolbox Development (WP2); and Pathway Quantifications (WP3).

To facilitate achieving objectives A and B we sought feedback on the D1.1 pathways from the groups identified through a combination of in-person and online workshops, plus interviews and written exchanges with selected experts. Full details and results of these feedback sessions may be found in the appendix to this report, including summaries of the selected expert feedback sessions which are not detailed here. Following are three summarised accounts of three workshops used to receive feedback on the D1.1 pathways from: Project Partners; The Stakeholder Group; The Broader Community. Meeting objective C is an ongoing process. Results of the initial downscaling exercises of key KMGBF targets are presented in this report and in an associated database (Nowak et al 2025, RAINFOREST D1.3). Appendix 2 of this report also contains a set of tables detailing the preliminary parameterisation of the elements of the VITAL-PATHS-FOOD. Note that not all the variables included in the pathway are intended to be, or could be parameterised, but are none-the-less included to allow researcher to better visualise and comprehend the socio-political context which the pathways exist within.

§2.5.1 RAINFOREST Milestone Five Workshop – IIASA - October 4th 2024

In October 2024 members of the RAINFOREST project consortium met at *The International Institute for Applied Systems Analysis* (IIASA) in Laxenburg, Austria for a two-day hybrid meeting which had been pre-agreed as a "milestone" session of the RAINFOREST HEU project where feedback on D1.1 would be sought from project partners responsible for the WP3 & WP4 case studies. The aim was to utilise insights from the ongoing project case studies to explore the coherence and consistence of the pathways in the context of the case studies, across the "narrative elements"

(Sectors: agriculture, forestry, conservation & restoration, energy, finance; Institutions: governments, markets & trade, IPLC); and to find examples of interventions from the case studies which could exemplify elements of the pathways. Feedback was collected through half-day sessions devoted to each of the pathways, conducted in a world-café format and followed by a plenary session. Each group discussed the coherence of the narratives, the policies which might predominate in each pathway, and modelling choices which could be employed.

§2.5.2 Governing Sustainability Transformations Workshop -WCSG – Oct 16 2024

On 16th October 2024 researchers from the RAINFOREST project hosted a workshop at the *Wageningen Centre for Sustainability Governance* conference "Governing Sustainability Transformations" [WCSG Workshop] to gather feedback from the broader research community on sustainability transformation, to better understand the coherence and internal consistency of the narratives; to identify potential revisions; and to assess how well the existing narratives tracked the expert-opinions on how sustainability transformations could develop. The workshop was designed according to a story-and-simulation approach, where experts were invited to select a pathway which best tracked their personal justice and value-of-nature preferences and asked to: suggest the revisions to the consistency of the pathways; critique and defend their preferred view in light of perspectives from the other pathways; and identify policy responses thought to be consistent with their preferred pathway based on a policy-simulation task designed around one of the RAINFOREST project case studies. Additionally, a stakeholder mapping exercise was conducted to identify which stakeholder groups were thought to be the chief supporters and opponents of the pathway.

§2.5.3 Actors and Motivations in Food-Systems Change – Hybrid - March 17 2024

On March 17th we hosted a hybrid workshop to elicit feedback on the D1.1 pathways from food and biomass system stakeholders: including businesses, NGOs and CSOs, governance actors, research, and conservationists. The workshop began with two

breakout group sessions, where participants self-selected into groups to discuss: “market or non-market” interventions; followed by “global scale” or “local scale” interventions. Participants were tasked with mapping key stakeholders, and explaining why they thought they preferred interventions of this type. Their responses were recorded and presented back to them, mapped onto a x-y axis of market-nonmarket / global-local. In the remaining plenary session, participants looked at each quadrant of the axis in turn, and commented on feasibility considerations, and blocking & enabling actions which would be needed for each quadrant-scenario to make biodiversity positive actions. This allowed us to check against a proxy for our D1.1 pathways to evaluate whether we had correctly identified the relevant actors, and to understand from stakeholders in the system their perspective on the feasibility of each pathway.

§2.5.4 Invited Expert Feedback

In addition to the feedback workshops we also reached out to a selection of international experts to give targeted feedback on the scenarios as a whole, and on specific interventions and features of the pathways. These sessions involved circulating drafts of the pathways (from D1.1) or sections of ongoing revisions for comment, followed by interviews with the experts for further clarification. A full compilation of the feedback received may be found in Appendix 1.

§2.5.5 Feedback from the quantitative applications

Feedback was collected from two on-going quantitative applications conducted in the RAINFOREST project: the translation of global action targets from the KMGBF to national scale (see section B “DATABASE ON DOWNSCALED BIODIVERSITY TARGETS’ in this deliverable), and the quantification of the pathways with an integrated assessment modelling framework (see Appendix section ‘C2.Preliminary parameterization of the pathways in GLOBIOM’ in this deliverable). The main type of input from these applications was affecting all pathways and primarily consisted of specific considerations on what dimensions (e.g., referring to Table 5 in this document, Sub-Variants/Narrative Elements) and descriptors (e.g., referring to Table 5 in this document, Indicative Questions/Description) are essential to these

quantitative applications, and therefore need to consistently be described in across all three pathways. For example, when it comes to the quantification of the pathways, a crucial aspect shaping both the provisioning services from agricultural systems and their environmental impacts relates to what the various possible changes in crop production methods (agroecology, precision farming, organic farming) might imply in terms of yields and input use efficiency. We therefore agreed on a typology of production methods to be systematically specified for each pathway the foreseen evolution of the shares of various crop production methods. Moreover, concerning downscaling selected KMGBF targets, e.g., target 3 on area-based conservation, crucial questions to consistently address in the pathway narratives were how the targeted 30% of land conservation should be distributed and how strictly they ought to be protected, aligned with the underlying value perspectives and justice preferences of the pathways. Such feedback was gathered through an iterative development of the detailed pathway assumption table (see Appendix 'C4. VITAL-PATHS-FOOD Pathway Assumptions Comparison Tables'), which were used to produce the long narratives and revise the short narratives and the short comparison table.

§2.5.6 Consolidated Findings from Feedback Sessions

This section details the major findings of the feedback sessions, including the reflections on the coherence of the pathways, feasibility constraints, enablers and barriers, and the motivations of the actors involved, plus he suggested revisions for the D1.1 pathways. In general, it was found that the draft- pathways had a strong alignment with the expectations of our reviewers, and feedback focussed predominately on areas where the pathways could go into greater detail, rather than revision of the elements of the pathways themselves.

Global Green Innovation

Feedback on this pathway on the relationship between markets (as the key driving force of the transition) and what role if any government actors would play. In the WCSG pathway there was a desire expressed amongst participants for greater distinction between this pathway and *Global Stewardship Towards Co-Existence*.

In terms of feasibility, at WCSG proponents of this pathway argued that technology-based interventions have (at least occasionally) be an alternative for behavioural and value shifts, and thus the focus on substituting unsustainable products in this pathway offered a plausible mechanism for enacting a sustainability shift. Likewise, in the M5 workshop, participants argued that the focus on market-based interventions does not rely on a radical break from business-as-usual mechanisms and prevailing values; and to this extent makes the pathway politically feasible.

The chief barriers to this pathway were thought to be incentives for the market to voluntarily shift towards sustainability and biodiversity positive actions. Suggested motivations were that businesses might voluntarily shift towards sustainability as a way of hedging commercial risk, based on a long-term calculation that ecological breakdown would impede profitability; and acting in a timely fashion would mean less had to be invested in recovery than in a scenario where there was greater ecological breakdown. However, in Actors and Motivation there was still a worry that companies might be structurally unable to make these long-term investment decisions where there are incentives to adopting less sustainable production methods to undercut their business rivals, unless there was a governing actor who could coerce the market towards adopting sustainable measures by shaping marking conditions and incentive structures.

Likewise, a feasibility constraint was identified as consumer willingness to pay for sustainable products. This pathway was identified in relying first on a consumer base willing to pay a premium for sustainable products, and in Actors and Motivations concerns were raised about whether there was a market globally for these products which could form a reliable basis for a broader transition.

Across the feedback series participants consistently identified similar beneficiaries and losers of the pathway. In WCSG participants identified multi-national corporations, including the tech, fossil fuel, and meat industry as clear winners. In Actors and Motive large business across the value chain including both producers and retailers were put forward as chief beneficiaries. WCSG participants raised

marginalised communities as blocking actors, who see this pathway as continuing a world-system which has marginalised them and their interests. They raised the possibility of protest and even violent resistance as possible actions if the continued to be systematically excluded from the benefits of the economy and had their interests marginalised in the transition. However, the chief blocking action to this pathway was thought to be competitive pressures from businesses themselves, and the lack of mechanisms for coordinating action and shaping incentives towards sustainability.

Global Stewardship Towards Co-Existence

Across feedback sessions, participants identified that the key feasibility challenges for this pathway the upscaling of global institutions and governance. In the WCSG workshop, participants identified the fact that there are existing institutions such as the U.N. was favourable to the feasibility of the pathway. Proponents of the pathway argued that this pathway was plausible since it builds on existing institutions rather than a global shift in values. They drew attention to the fact that amongst the D1.1 pathways this scenario has a plausible mechanism for coercion and enforcement, while also being tempered by democratic accountability. However, in the M5 workshop and the Actors-and-Methods participants saw the constraints to the ability of these existing transition to the political forms they would need to fulfil the role they play in this pathway. In Actors-and-Methods participants discussed the fact that in our world, international institutions are limited in funding and mandate and have difficulties in making agreements or setting global standards. In the M5 workshop it was identified that global governance of food and biomass systems would need a different institutional set up to the one which currently exists, and current institutions are comparably weak. It was discussed that “historical responsibility” as a feature of the pathway should be moved to Needs-Based and Nature-Connected Local Stewardship, as accepting historical responsibility has been a major impediment to some states’ willingness to participate in global agreements such as the Kyoto Protocol.

Relatedly, a topic of discussion in the M5 workshop was over the level of command-and-control being presumed in this pathway. It was deliberated on how better to

distinguish the pathway from Global Green Innovation, with a discussion over different visions of "efficiency" playing out in the pathways, In Global Green Innovation efficiency is interpreted as cost-effectiveness, by allowing the market to take responsibility for the transition and keep costs of transformative change off public-ledgers; whereas in global stewardship efficiency is achieved through coordinated central planning, leveraging economies of scale, and "good-enough" one-size-fits all solutions which accords with a top-down and expert-led procedural system. The perceived challenge of making progress on social/poverty-elimination aims while also have an ambitious approach to conservation (in line with its nature-for-nature valuation of nature) means that efficiencies need to be found somewhere; even while enacting its intrinsic valuation of nature means that this pathway is willing to eschew cost-effectiveness in how it sites and locates its protected areas.

Another question raised in the feedback was about the role of large/major corporations, and multinational businesses. While these were identified as key players in Global Green Innovation, participants in the feedback sessions gave diverging accounts of how they saw these entities behaving in this pathway. In the WCSG workshop some participants saw this pathway as being unfavourable to these actors, as it had both means and motivation to try and threaten their profit-making ability. Global institutions could set global standards and crack down on regulatory avoidance. Corporations might also fear that a global governance regime committed to redistributing wealth globally and engaging in command-and-control style economic measures to achieve this might threaten their assets with seizures and nationalisation, or seek to limit their ability to profit in key sectors of the global economy such as an agro-forestry sector which is being increasingly compelled by governments to produce goods to meet global needs (e.g., maximising calories or high quality nutrients/area to save space for nature while eliminating global poverty) rather than the optimally profitable ends.

However, within the same workshop, other participants raised the prospect that some (though not all) business, perhaps the largest market players, might be able to succeed in this pathway if they were able to negotiate their inclusion in the new regulatory order. Powerful market actors might attempt to "capture" new

institutions and ensure that the regulatory landscape which they create remains beneficial to them. This might allow them to eliminate smaller competitors and ensure that they continue to be key players in the new order. Conversely, in Actors-and-Motives some participants argued that rather than market-leaders, smaller industry front runners employing sustainable practices might be the key beneficiaries, as they understand that their business model is predicated on enacting a regulatory shift. They might welcome a globally oriented raising of standards as a means of closing the gaps with their competitors.

Potential losers for this pathway were thought to be IPLC. In WCSG some participants were concerned with the envisioned strong regulation of new protected areas, which coupled with a strategy of eschewing cost-effectiveness for landscape connectivity raised concerns about the potential for displacements and a return to "fortress" style conservation efforts. Similarly in Actors-and-Methods participants noted that the feasibility challenges of a global governance system facing questions of funding and mandate is compounded if the aims is to financially incentivise a transition that is fair to small farmers. They also noted that while the global top-down outlook would be beneficial/necessary to scale and govern the transition, these institutes might lack the granularity to effectively manage the transition at a local scale in a way which is sensitive to local variations in circumstance, culture, preferences, and crucially the locally specific dynamics of biodiversity.

Needs-Based and Nature Connected Local Stewardship

In all of the feedback sessions, participants focused on perceived feasibility constraints for a pathway which relied heavily on a shift in ethical values, with such a strong focus on voluntarism and good-will. At the M5 workshops participants were curious about the role of government in facilitating the transition; whether government would just empower subnational actors with enhanced decision-making authority to manage their own affairs, or whether they would maintain authority to coerce and guide regional governments towards sustainability. Other feasibility constraints were identified in the Actors-and-Motives workshop, including barriers/lack of a reward structure to consumers making sustainable choices, and knowledge barriers and information sharing to enact transitions.

Conflicting opinions arose as to whether regionalisation would produce more or less ambitious actions, with some workshop participants raising concerns that some local/traditional cultures might be poorly aligned with global sustainability goals. Similar points were raised at WCSG with participants raising concerns that the lack of coercive enforcement mechanisms and the perceived focus on voluntary measures enabled by a broad shift in values presenting a barrier to transition. Additionally, they raised concerns about how individuals who were not aligned with the values of the pathway might be treated, and how they could act as blockers to change.

Feedback session participants consistently mapped the same actors as enablers and blockers. The chief beneficiaries were thought to be IPLC and marginalised groups who under a system with substantial political devolution could expect to achieve greater power to advocate for their own interests and live lives in accordance with their particular visions of justice and the "good life"; while concurrently pushing for ambitious sustainability measures. In the Actors-and-Motives workshop, the devolution of political power was also thought to enable IPLC communities to adopt environmental management options and pursue interventions which were highly customised to the cultural and environmental circumstances – and this was thought to increase the feasibility of any particular intervention.

This pathway's focus on a shift to a "needs-based" economy would raise blocking actions from actors who are currently prominent and powerful in today's world. Participants in WCSG saw the fact that this pathway involved a fundamental shift in the priorities of the economy in this way marked this pathway as the only truly "transformative" option; and also was necessary to enable a shift to a non-anthropocentric valuation of nature. The link between the economic restructuring and a shift away from a purely instrumental valuation of nature was also highlights in Actors and Motives.

While much of the feedback on this pathway focussed on a demand-side voluntary shift, the mechanisms of production were also discussed. In Actors-and-Motives, participants argued that this pathway with its focus on reduced global trade and

regionalisation might be motivated by a desire from governments and people in the global south to break with a predominately export driven commodity production economy. A shift towards production to meet local needs could align with a desire for revenue diversification and a securitisation desire to onshore production. These ideas are discussed further in the following section.

Summary of Suggested Changes to be Incorporated into the Redrafts

1) For Global Green Innovation there needs further distinction from Global Stewardship Towards Co-Existence pathway vis a vis the role of government oversight and intervention in the market.
    - For Global Green Innovation we should emphasise the motives for the market to voluntarily transition, especially reducing transition risks and securing the conditions of profitability into the future.
    - For Global Stewardship Towards Co-Existence historical responsibility should be moved to Needs-Based and Nature-Connected Local Stewardship to reflect the feasibility constraints of reaching global inter-state cooperation.
    - For Global Stewardship Towards Co-Existence the role of command-and-control policies should be clarified, and be used to distinguish the pathway from Global Green Innovation
    - For Global Stewardship Towards Co-Existence we should clarify the role of large corporations and how they respond to a new regulatory environment.
    - For Global Stewardship Towards Co-Existence and Global Green Innovation we should highlight the competing accounts of "efficiency" between the pathways.
    - For Global Stewardship Towards Co-Existence we should highlight the compromises global governance organisations have to make in the face of feasibility constraints
    - For Needs-Based and Nature-Connected Local Stewardship we should clarify the role played by national government in the devolution of political authority.
    - For Needs-Based and Nature-Connected Local Stewardship we should incorporate "Historical Responsibility" and frame it as a motivation for individuals and communities reducing consumption in the global north.

- For Needs-Based and Nature-Connected Local Stewardship we should discuss and clarify in the pathway the feasibility constraints which arise from a reduced ability to coordinate action globally or enforce compliance.

§2.5.7 Future Steps for the Pathways

The RAINFOREST Pathways currently depict very high-level abstractions of global level changes to food and biomass systems. We envision the major task for further engagement with the pathways will be exploring how each pathway might look on a sub-global scale and applying them to specific contexts, industries, sectors, and issues. Future research should focus on understanding in greater detail how each pathway might operate within each section of the value chain, or within specific national, regional, or local contexts.

The VITAL-PATHS-FOOD pathways seek to depict differing justice preferences and values of nature, and this report has detailed how we aligned the pathways across these values. Nonetheless additional research could help us better understand the isomorphy between "nature-value" and "justice-preferences". Workshops with stakeholders/general public could help understand how and why people make connections between their beliefs about fairness and the way they value nature. Likewise deeper engagement with the philosophical literature and applied philosophical methods might allow us to better understand theoretical reasons why particular justice perspectives and ways of valuing nature are either well or poorly aligned.

Future research could also consider other justice perspectives. The aim of the pathway project was not to be exhaustive and consider every possible account of fairness – but rather to concentrate on prominent theories within western political philosophy. Further research could consider the possibilities of additional pathways representing different justice views. In Appendix 3 we note that feedback received pointed us towards considering an additional (4^{th}) pathway reflecting a justice viewpoint focussed on national sovereignty and nationalism – and a short outline of key themes of this pathway is included there. But other views on justice exist and could in theory be developed into pathways. Likewise, with a broader and deeper engagement process the depiction of each worldview in the pathways could be

further refined in reference to the worldviews of stakeholders, rather than relying on engagement with political theory.

§3 Short narrative description

Drawing from the streams of feedback summarized above and the draft narrative pathway descriptions found in D1.1 (see D1.2 Table 1) we created three scenario pathways which depict plausible positive futures where transformative change is achieved to the benefit of biodiversity, climate, and human development; and which systematically trade-off on both perspectives on justice (distributional, procedural, and recognitional (Hanger-Kopp et al 2024)) and the Nature Future Framework valuations of nature (Duran et al, 2022). The following section gives long narrative accounts of these futures. Condensed versions systematically breaking down and comparing the key variables may be found in Appendix 4.

§3.1 International Market Innovation (IMI)

This pathway sees green growth, powered by innovative new technical solutions, as the key to managing the twin crisis of climate change and biodiversity loss while continuing to achieve economic development. In this world transformative change is driven by private actors and enabled by a permissive regulatory environment geared to stimulating investments into nature and a revolution in green technology. Instead of hitting the breaks on economic growth, societies see green-growth, market competition, trade-liberalisation, and technological innovation as essential for breaking the link between development and biodiversity loss. A 4th agricultural revolution radically improves production efficiency, allowing more to be produced for lower inputs and on less space, allowing more room to be found for biodiversity. Globalisation remains a dominant force in the world-system, and global corporations and multinationals freely move money and resources across borders, allowing both primary production and conservation to be allocated to globally cost-effective regions. Nature is understood as the instrumental basis upon which all human wellbeing relies. Private companies see halting biodiversity loss as essential for maintaining the long-term conditions needed for profitability, and invest in repairing and maintaining nature's contributions to people in order to secure their access to

ecological surplus long into the future. A utilitarian vision of justice predominates. States seek cost effective ways to manage the ecological crisis by allow the market to play a leading role and allowing the costs of transition to kept off public ledgers. Instead, the government sees its role as shaping market conditions through policies such as biodiversity offsetting. There is a strong respect for individual property rights and individual liberty; as matter of procedural justice the government plays a minimal role in containing citizens freedom to act. Compared to the other pathways this world is a wealthy world, and raising the overall wellbeing of the world is thought to be the best method for progressing on global social goals.

§3.2 Global Sustainability Orchestration (GSO)

In this world people see the conjoined challenges of biodiversity loss, climate mitigation, and global inequality as requiring an unprecedented level of global cooperation and coordination. States allow intergovernmental organisations to play an ever-greater role in orchestrating the transition to a biodiversity positive world, including allowing them to impose and standardise regulations across borders, redistribute resources, and coordinate production to tackling poverty and ecological breakdown. Protecting nature is seen not only as essential for providing for human beings but also viewed as a moral requirement on account of respecting nature's intrinsic value. The rights of nature are increasingly recognised and represented in global institutions, and as well as governing in the interests of the globally worst off, international organisations understand their mandate to include governing in the interests of nature. Respecting the rights of nature is thought to entail a conservation strategy focussed on devoting significant portions of global protected area targets to expansive, highly protected areas, large enough for natural processes to occur with little to no human influence. Making space for these border-spanning natural areas while closing the global inequality gap is seen as a major coordination challenge requiring new forms of global governance. To manage this coordination problem, procedurally citizens allow decision-making power to be increasing delegated to scientific and economic experts. Governments are given increased authority to shape individual actions, in order to lower consumption in the global north and save planetary space to raise consumption in the global south. A prioritarian understanding of justice is rooted in governing institutions, who see it as their duty

to ensure that the economy is reorganised to benefit the globally worst off first.

§3.3 Local Commons Stewardship (LCS)

In this world societies "think global and act local" (Tarantola, 2013). Communities see their intimate connections with and knowledge of their localities and eco-regions as their strongest asset in the fight again biodiversity loss and environmental breakdown. In order to capitalise on this asset, decision-making authority is increasingly devolved away from national and global fora and put into the hands of new, highly democratic and localised institutions. The small scale of these communities facilitates participatory political forms, and individuals are often very close to the centres of decision-making power. These institutions operate under highly communitarian worldviews, committed to fostering egalitarian ways of living amongst their members and promoting ways of living deeply rooted in a culturally significant relationship with their natural environ. The landscape is a patchwork of biodiverse farm and forest land, with only minimal land devoted to highly protected areas to protect especially interference sensitive species. IPLC knowledge is highly valued in charting a course to locally specific sustainable ways of living, and the devolution of political power sees many of these groups achieving sovereign political statuses previously unachieved. Rejecting the human-nature dichotomy, these communities aim to co-conserve biological and cultural diversity. There is a shift towards labour intensive and spatially extensive farming systems – with low inputs and low biodiversity impact. Communities produce much of what they need locally – consumption is lower as people shift towards traditional diets suited to their bioregion. Internationally, communities in the global north recognise their historic overconsumption and disproportionate impact on biodiversity and seek to make reparations by taking on a greater share of the burdens of the transition.

VITAL-PATHS-FOOD: Short comparison table

Table 7. Vital-Paths-Food Short Comparison Table

	International Market Innovation	**Global Sustainability Orchestration**	**Local Commons Stewardship**
Relation to Sustainable Development Pathways	Economy Driven Innovation	Managing the Global Commons	Resilient Communities
Relation to New Narratives for Nature	Sharing Through Sparing	Arcology/Sparing and Sharing	Dynamic Natures
Axis alignment	Global /Market	Global/Non-Market	Local/Non-Market
Distributive Justice	Utilitarian – the greatest good for the greatest number and high marginal utility in resource allocation. Market efficiency leading the way.	Prioritarian – ensuring that benefits accrue first to those who are worst off. Strong focus on poverty elimination.	Egalitarian Locally, Limitarian Globally. Local communities share what they have equally, and globally there are limits on overall consumption
Procedural Justice	Market focused, laissez-faire and free trade.	Expert-led global governance, liberal institutions. Cosmopolitan democracy.	Participatory democracy, highly devolved decision-making powers.
Recognitional Justice	Liberal formal equality. Market actors and	Robust global liberal order expanding formal	Devolved authority expands IPLC in their territories,

	property rights.	access, but trade-offs with abstracted authority.	but communitarian focus means state involvement in cultural sphere.
EU in a Global Context	EU is a center for global private sector led efforts, leading in innovation. Market forces seeking high marginal utility dictates most land use change occurs outside of EU.	EU is a one regional block amongst many, contributing to a global governance regime. EU gets some grandfathering exception to ensure participation, but also plays a key role in financing transition.	Authority within the EU see further regional devolution as regional communities are given more say in how they manage their local environment. EU recognizes its outsized responsibility for biodiversity loss and finances transition.
Forestry	Forests play a central role in offsetting carbon and providing an abundance of material to support a green-growth agenda. Fast growing short rotation stands are preferred to produce as much as possible on the least land.	Global institutions coordinate production and distribution of forests to meet long term strategic ends. Space saving principles are preferred but the reduced impetus on market efficiency allows for longer rotation high quality wood	Forests are integrated into expansive agricultural landscapes, and provide a wealth of long lasting products, and ecosystem services. People have strong relationships with their forests and manage them in

		products and quasi-natural forests.	low impact, culturally valuable ways.
Agriculture	Producers are incentivized to find ways of intensifying agricultural production through precision techniques and technological innovation, allowing land to be spared for nature. Market mechanisms such as biodiversity credits and payments for ecosystem services allows the market to price externalities and find high marginal utility locations for agriculture and save space for nature in least productive regions.	Sector wide coordination focusses on achieving intensification and economy of scale, through system wide efficiency gains, precision agricultural techniques, investment in logistics and mechanisation in order to spare land for nature. Agriculture is globally coordinated to prioritise production in regions with high ecological capacity.	Agriculture reduces its impact on biodiversity through a widespread shift to low impact and organic production methods. These labour intensive and low input systems foster strong cultural relationships with food production, and people have ties with their local biomes through the food they consume, which is often produced very close to where it is consumed. Agriculture is low yield but expansive, often integrated into semi natural and protected areas.
Trade and	Circularity of	Increased role for	Supply chains

Intermediate Value Chains	resource use achieved through improvements of waste products. Efficient cost-effective global transport of goods.	state actors at the expense of private sector. Global institutes set fair prices to ensure food security is maintained.	shortened and consumers take a bigger role in organizing production through cooperatives. Sitings and production priorities set democratically.
Protected Areas	Market optimized locations of PAs with efforts to maximize NCP delivery. Extensive use of biodiversity credits to lower the costs of development	Focus on sparing as much land as possible for nature, priority devoted to expansive connected areas. Secondary focus on NCP delivery.	IPLC rights leads to land-sharing strategy, where PAs only used in essential circumstances. Communities retain control over their territory and avoid displacement.
Sustainable Consumption	Overall consumption remains high compared to the other pathways. The focus is on breaking the link between consumption and negative environmental outcomes by	Consumption reduced and reprioritized. Overconsumption in high consuming regions today reduced to make space for raising consumption in others. Governments act to drive down	Consumption substantially reduced as globally consumption switches towards planetary health diets. Citizens of global north countries substantially reduce consumption to

	substituting harmful products with environmental alternatives, such as novel protein sources. Substitution of products for alternatives reduces need for a strong shift in preferences.	consumption of high impact products via taxes/regulation, esp. in the global north, and reprioritising resource use to support development and poverty elimination.	allow space within planetary boundaries to allow consumption to raise elsewhere. Shift is primarily demand side driven as values shift towards a preference for using less.
BioEnergy and Carbon Capture	Energy demands remain high to support growth, and bioenergy is a bridging technology to CCS development	High land demand for PAs and Agriculture makes BECCS prohibitively expensive. Coordinated nuclear buildout.	Little space left over for bioenergy with the focus on space sharing. Focus on distributed energy systems.
Finance	Private sector led financing enabled by a lowering of trade barriers. Governments play a role in shaping markets to direct capital in nature positive investments.	Powerful states do not contribute according to responsibility, but still pay highly into new global financial mechanisms. Extensive ODA to compensate PA opportunity costs.	Locally, financial instruments transformed to transition to needs based economy. Globally historic responsibility leads to novel financial mechanisms to facilitate north-south capital flows.

Government and Institutions	Governments play a modest role in shaping market conditions and regulating biodiversity and carbon offset markets.	Global institutions play an increased role in economy and politics. States endow global institutes with the power to make decisions concerning their economy and territory.	Power devolved from global institutions to local and regional levels. This facilitates a democratization of increasing areas of life and the economy. Governments facilitate needs-based redistribution to progress towards global equality.

VITAL-PATHS-FOOD Narrative Descriptions

§4 International Market Innovation

§4.1 Overview: Valuation of Nature and Justice Preferences

In this future transformative change is driven by a globalized market economy supporting a growing green economy. The private sector plays a key role in driving the development of new technologies, methods, products, and production techniques which successfully decouple economic growth from biodiversity loss (Hickel & Kallis, 2019; Briggle, 2024; Pielke, 2010; Stoknes & Rockström, 2018). A utilitarian worldview which prioritizes maximizing the total aggregate good for the lowest cost leads to the market taking the prime place as a distributive mechanism (Riley, 2018). Nature is valued for its instrumental value in driving and supporting human development, and it is thought that the best way of preserving nature is to use it (Hulme & Murphree, 1999). The state and super-state organizations play a minimal role supporting basic social welfare and regulating markets to support competition so that investments can be made in biodiversity friendly ways and ensuring that externalities are accounted for. An extensive network of protected areas is made possible through technology driven agricultural intensification and designed and distributed to produce high marginal utility by maximizing ecosystem services benefits and lowering lost opportunity costs. Often these are privately managed in order to keep government spending to a minimum and are financialized through a commercial valuation of ecosystem services via tourism and recreational activities and thriving Payments for Ecosystem Services market. There is a thriving market for carbon and biodiversity offsets, which are thought to be the most effective way of aligning growth and development with environmental aims, especially as a market-led way of identifying and managing land for protected areas. Ecosystem services are quantified and given market valuations so that negative environmental externalities can be accounted for through market-decision making. Market actors and corporations are motivated by both physical risks to their assets, the increasing cost to investment that ecological breakdown threatens and thus see

nature as a productive investment necessary for continuing to secure their access to 'the free gifts of nature' (Burkett, 1999), and transition risks.

Trade barriers are lowered allowing for multi-national entities to efficiently move resources and technology across the globe to provide the most efficient production of goods and utilization of natural resources. Efficient methods of production and a focus on new technologies and innovative products somewhat obviate the need for widespread lifestyle and consumer changes – e.g., through a shift away from meat, and an overall reduction in consumption. Where change is unavoidable, the market prioritizes development of novel consumer products such as plant-based meat alternatives that closely match the preferences of consumers in high-income countries. Technological innovations lower the biodiversity-impacts on both supply and demand sides of food and biomass value chains.

This world is a wealthier world, and moderate progress is made towards lifting those worst off out of poverty, but owing to a utilitarian focus on justice the aim is not necessarily to reduce overall inequality. Indeed, it is thought that even wide gaps in equality are justifiable to the extent which they are necessary for achieving an overall increase in wellbeing for humans and nature.

§4.2 Justice Preferences

§4.2.1 Distributive

This scenario represents a utilitarian understanding of distributive justice. The belief is that governments and society should pursue actions which generate the highest overall/gross utility for the greatest number of people (Mill, 1863; Hare, 1989; Singer, 1993; Riley, 2018), ensuring that investments in nature and society produce the greatest benefit for the lowest cost (i.e., high marginal utility); with no explicit consideration for the relative distributions of those benefits. In practice, within the pathway this entails utilizing market mechanisms to progress towards distributions which minimize costs overall while securing high marginal utility solutions (Riley, 2018). Because the overall aim is cost-effectiveness and optimizing the benefits of investments, this pathway does not aim to narrowing or eliminating inequalities.

Indeed, inequalities both globally and within states are understood to be compatible with, even a necessary aspect of, improving overall welfare because a certain amount of inequality is thought to be necessary to the functioning of a market system.

Societies see an expansion of property rights and liberal values as a core tool for improving environmental outcomes, as a clear system of property rights is needed to clarify responsibilities for the land, for enabling a payments-for-ecosystem services, and for enabling a fair and equitable sharing of the benefits of natural resources (Naughton-Treves & Sanderson, 1995). Nonetheless, globally, progress is made on narrowing the gap between rich and poor as global inequality drives biodiversity loss (Mikkelson et al, 2007; Holland et al, 2009; Hamann et al, 2018) even a market-led utilitarian distributive system can see instrumental benefits to reducing inequality in order to better preserve and secure the ecosystem services needed for a flourishing global market system. Protecting its access to nature's bounty requires the private sector to invest in both nature itself and the global poor, securing them good jobs and incomes which allow them to transition away from lifestyles that damage biodiversity and climate (IPBES, 2019: 196-7).

§4.2.2 Procedural

The market plays the leading distributive role in this pathway, and in service of allowing market mechanisms to reach optimum and efficient outcomes the state plays a comparatively reduced regulatory role. Liberal democratic state institutions exist, but the state manages comparatively fewer areas of the economy and life. People are expected to take increased responsibility for their own actions and impacts and can participate in public and environmental priorities through their behaviours as consumers – by selecting from a wide range of consumer products, creating demand-side shifts, and making sustainable investment choices. Property rights are thought to be central to fair procedures, and all are formally able to engage in business and dispose of their property within the framework of democratically agreed upon environmental regulations, and in accordance with the rules which govern fair market interactions.

The utilitarian nature of this pathway means all procedures have to be ranked against their social costs (Posner, 2011; Meyerson & Mackenzie, 2018). There is recognized to be trade-offs between including ever greater numbers of participants into democratic decision making and the efficiency of allowing actor to take swift actions needed to limit climate change and halt biodiversity loss. In this scenario, it is thought that by allowing the market freedom from overly burdensome regulation and democratic oversight (for instance, in the form of strict planning regulations, long consultation periods, or government command-and-control decisions) that greater cost-benefit and overall utility for both people and nature can be achieved.

§4.2.3 Recognitional

According to similar reasoning, this pathway has modest engagement with widening recognitional justice beyond a formal liberal recognition of the equality of all as loci of utility whose preferences need to be accounted for in environmental decision-making. Ownership and equal individual rights to non-interference are understood as central to a functional and predictable market and there is little incentive in this pathway to deepen or widen the recognition beyond this. However conscious consumers are able to exact some pressure on market institutions to cater to their needs.

In some circumstances there is a formalization and legitimation of the customary ownership systems of IPLC groups where the market sees this as the optimum strategy for making the lands under IPLC management legible to an ecosystem services market, allowing IPLC to capitalise their holdings. Nonetheless as the utilitarian approach to justice focusses on delivering the greatest benefit for the greatest number, IPLC property (as with any other properties on the market) are subject to being bought and sold, if the market determines there is a sufficiently large benefit to gained. States play a comparatively minimal role in ensuring that market forces have some control tempering them to ensure IPLC are able to benefit from participating in the global economy.

The market and the assumptions which underly it is broadly unquestioned and there

is consequently little room for plural epistemic frameworks for understanding nature's value outside of rational instrumentalism. Epistemic justice is instead understood through the fair sharing of information which is thought to be necessary for efficiency in market operations, and one of the government's roles is ensuring that adequate social and environmental reporting standards are adhered to, so that externalities can be properly assessed and optimal utilitarian distributions can be progressed towards.

§4.3 Value Chain Segments and Interventions

§4.3.1 Agriculture:

In agriculture the focus is on saving space for, and reducing pollution of, nature while meeting the comparatively modest reduction of consumer demand through an intensification of production. Market innovation drives the development of highly efficient precision farming techniques which allows for a flattening or reduction of total cultivated area allowing some areas currently under cultivation to be restored and reallocated for nature. Likewise technological and precision farming advancements facilitate a reduction in pollution and fertilizer use, lowering the overall impact of intensive farming systems (Chen et al, 2022). Agricultural intensification leads to a landscape pattern of high intensity areas interspersed with semi-natural land positioned for optimal ecosystem service provision. Governments and the market work together to develop a regulatory system to accurately give a financial valuation of ecosystem services allowing this to be incorporated into spatial planning and ensuring negative environmental externalities are accounted for.

The state plays a supporting role in designing regulatory frameworks under which the market can best be incentivized to promote biodiversity aims; although there is a political balancing act between state regulation and the market fearful of restrictions stifling innovation. Regulation is designed to promote farming methods which maximize production while minimizing space and pollution, and biodiversity crediting/offset systems act to streamline the planning process by allowing the market to reach an optimal distribution of the highest quality land for agriculture while reserving adequate space for meeting biodiversity aims and securing ecosystem

services. Biodiversity offsetting regimes are central to the operation of this pathway, as these create incentives for producers to find methods to raise yields as the price of opening up new land for agriculture rises.

Agriculture is highly mechanized and technologically developed. Achieving precision-based agroecological intensification requires a high degree of novel technological development in this pathway, but also an expansion of the use of already existing agro-technologies. There is substantial high-tech technological incorporation including laser levelling, global positioning systems, and spatially explicit yield monitors to improve input use efficiency and reduce environmental harm associated with fertilizers, pesticides, and above-ground irrigation. These high degrees of automation reduce labour requirements across the system while raising the skill requirements. Technological improvements in precision irrigation allow for lower amounts of water use to achieve the same results. Increased mechanization decreases the labour inputs in agriculture, freeing up ever greater numbers of workers to enter urban labour markets – and ultimately depressing labour value (Syrquin, M., 1988). Agro-businesses become major collectors and users of big data, and utilise it as part of proprietary agricultural technological systems.

This pathway sees the highest increase in yields out of the three scenarios. This is true both within OECD countries and non-OECD countries which see a substantial yield increase as precision farming techniques expand. The persistence of strongly market determined agricultural production in this pathway means that this pathway has a comparatively high degree of production which remains devoted to supplying the taste-preferences of an expanding global middle class, including cash-crops, and luxury resource intensive crops. Ultimately crop type is determined by market preference and those with high purchasing power are still able to exert a greater influence on what is produced. However technological substitution and a shift in preferences towards more sustainable diets, as well as market innovations into product substitution does temper this trend. The market still seeks to cater to the preferences for an animal protein rich diet but increasingly seeks technological innovations that can substitute meat for novel proteins. Likewise technological innovation in the meat production system lowers carbon and land-use footprint of

meat production. There is an intensification of remaining livestock production, aiming to produce more meat on less land and for lower environmental cost, and precision farming techniques applied to feedstock mitigates some of the impacts of meat production.

This pathway aims to restore degraded natural land mostly through saving space for nature by intensifying agricultural production, allowing land to be returned to nature without impacting overall production. Biodiversity offsetting and a pricing of ecosystem service provision incentivizes agricultural producers to identify land for restoration where they can get the highest marginal returns. Owing to the high technologization of this pathway, and the low dependency of staple crops on pollination, there is a comparatively low need for restoration to occur throughout or in close proximity to agricultural land in order to provide ecosystem services needed for production. Agricultural production regions tend to be highly specialized and mono-cropped, with low on-farm diversity, as the chief objective is raising yields to save space rather than restoring on farmland itself. Farms tend to be very large as large highly efficient farms outcompete smaller producers, and large uninterrupted field sizes aid mechanization and support precision techniques.

The 50% KMGBF nutrient loss target is achieved globally rather than per capita or per country. The central driver of nutrient loss is thought to be fact the market had no incentive to factor it into its pricing. Novel financing PES programs are developed (Including Nutrient/Water Quality Trading from non-point sources) so that producers have to account for nutrient loss when siting agriculture and creates an incentive to find ways of reducing nutrient loss on farms. A result of the pricing of nutrient loss is that farmers have to account for potential nutrient loss when choosing to use fertilizers. This leads to an incentive for fertilizers to only be used where doing so remains profitable once the cost of nutrient loss credits are factored in. This leads to the cost-efficient solution of fertilizers being allocated to the most utility-effective locations and uses. Achieving the production efficiency gains needed to support the high consumption in this pathway means that pesticide use is comparatively high compared to other pathways, but as the externalities of these products are price the market drives the development of less harmful alternatives.

§4.3.2 Forestry:

Forestry is governed by a principle of space-saving through market-efficiency and an intensification of production, while also optimising the delivery of ecosystem services as a form of nature-based-solution. The result is a mix of high intensity land sparing productive forests with well protected areas, as well as regions of sustainable use quasi-natural forest. The instrumental valuation of nature implies that the best way to preserve natural areas is to find uses them, and there is a mix of commercial forestry with high production which saves space for protected areas of native woodland and forest with minimal sustainable use. The overall strategy is for high-productive fast-growing plantations and protective plantations to produce valuable commercial products as well as to secure ecosystem services (e.g., floodwater management) in strategic locations, the high production of which allows space for naturally regenerating quasi- natural and protected forest elsewhere. A competitive market leads to foresters preferring fast growing plantations and low market timber prices, supporting high consumption and short-term need for carbon storage. Carbon storage is a major objective for forestry as consumption remains comparably high in this pathway, and fast-growing forest is needed to offset the higher emissions.

Forestry distribution is market-led with environmental objectives being incentivized through Payment for Ecosystem Services schemes and government set pricing of environmental externalities. The locations of new forests, as with agriculture, is determined through biodiversity & carbon offsetting to identify high marginal utility locations for forests while minimizing conflicts with productive agricultural land (Simpson et al, 2011). Globally new commercial forests are planted where growing conditions are optimal, including the development of roundwood plantations in the tropics. Timber is shipped worldwide, while the market allocates protected forest to those areas which are least accessible and amenable to commercial use.

Foresters take a permissive attitude to non-natives in plantations where these are useful for securing ecosystem services and are profitable investments, and do not substantially impact the overall health of neighbouring ecosystems or species. Owing

to a nature-for-society valuation of nature the naturalness of forests are not an objective *per se* where managed/combined objective forestry are shown to be able to make progress on biodiversity targets. At a landscape level, location planning is facilitated through a payment for ecosystem services program to locate forests where they can provide co-benefits such as flood control and other beneficial ecosystem service. The aim is to price in the services well located forests can provide in order to utilize market functions to find sites with lower value for intensive agriculture. On a global scale too, cost effectiveness/marginal utility is the chief determinant of the spatial distribution of forests, essentially wherever the market finds space for high intensity production. Typically, new forestry plantations are sited on cheap lands including in the global south, with roundwood production in the tropics, but also extensive new forests the high latitudes. Using marginal utility as the determinant for the placement of forests means that connectivity between sites is not inherently planned for (Jongman, R.H.G., 2002). However, the practical reality is that there can be generally good connectivity between forests as the market drives landscape specialization. Especially in the tropics there are large areas of forests needed to achieve carbon capture objectives.

An EU biodiversity offsets and a market for ecosystem services leads to a modest expansion of forests, both conservation and productive, largely on marginal or abandoned agricultural land. A coordinated payments-for-ecosystem-services regime leads to some strategic placements of forests to regulate water catchments and to attenuate nutrient loss. The high cost of land in mainland continental Europe leaves limited scope for a large forest expansion, however in high latitudes there are large areas of restored and protected forests. EU targets forests onto abandoned agricultural land and incentives forestry as a nature-based solution which can aid in flood water mitigation. Industrial forestry provides useful building materials that can serve a dual purpose in capturing and storing carbon. There are some efforts made through price incentive setting to ensure that non-forest natural lands are not converted to forest or agriculture, in order to halt the damage to rare habitats and to manage extinction risk.

§4.3.3 Trade and Intermediate Value Chains:

In this pathway there is a reduction in trade-restrictions, and a flourishing of the Washington Consensus vision of liberal globalization. Where states play a role is in setting market conditions in order to orient the market towards sustainable investments: pricing of externalities and strengthening of environmental regulations are seen as the price of doing business, but overall trade is liberalized and multi-national corporations play a central role in the global distribution of resources. The outlook is that through free trade, the market will be the most efficient determinant of global goods, increased trade allows greater specialization and greater efficiency gain and the most cost-effective way of managing the transition.

Market actors voluntarily take up sustainability standards and practices – out of recognition that farming and forestry will be unviable in a scenario of climate and biodiversity collapse, but also to meet a consumer demand for sustainable products. There are multiple competing private-led sustainability standards which are used for product differentiation to an ethical/sustainable-product-oriented consumer market. These competing sectoral standards and a sustainability conscious consumer base drives an upward pressure for companies to adopt ever stronger regulations. Companies make pledges and adopt good practice codes to reassure consumers that their products can be trusted. Likewise, intermediate actors such as wholesalers are motivated to purchase from sustainable producers in order to hedge against the supply chain breakdown that would occur if there was an ecological disaster. Sustainable products are seen as a “safe bet” by wholesalers and distributors (Inside Track, 2025).

Achieving positive biodiversity outcomes while keeping consumption high also requires a shift in substantially lowering loss before products reach market. Farmers and supply chain managers develop methods for reducing post farm-gate loss as part of a strategy for increasing returns, as biodiversity offsetting programs raise the cost of establishing new agricultural land thus creating a pressure to produce more with less space. Genetic technologies and new preservative techniques reduce spoilage, and technological advancements lead to more efficient processing stages with less

loss.

A competitive market is thought to be the best way to ensure that distribution networks are efficient. Long supply chains are needed to ensure production occurs in the most efficient growing regions. “Just in time” principles continue to be practiced and keep prices down, but increased computational power and moderate private investments into transport infrastructure lessen the wastages from this. A global lowering of trade barriers are thought to be the best way to stimulate competition and innovation, to make supply chains efficient, and allow companies to invest freely in infrastructure improvements across borders, thereby keeping global prices low.

Financial actors are key players in this pathway. The lowering of trade barriers allows capital to flow freely globally, and productive investments are made into capitalizing projects in the global south. Ecosystem services are seen as essential and productive investment opportunities. Novel financial instruments are developed to account for the value of ecosystem services and there is a robust global market efficiently delegating capital into productive ecological investments. The land-sparing approach drives up the cost of land, which in turn sees technologies which can quantitatively increase productivity of agriculture and forestry per hectare are also highly capitalized. High economic growth is pursued in the early stages of the pathway to drive innovation into these sectors in order to achieve the qualitative leap which decouples future growth from negative ecological outcomes.

§4.3.4 Protected Areas:

In this pathway the intensification of both agricultural and forestry production allows for overall space savings to allow new land to be designated as protected areas. Owing to the utilitarian account of justice in this pathway, states are concerned with ensuring that conservation is managed cost-effectively – and that the general public are spared from bearing the costs of conservation by keeping financing protected areas off of public ledgers. Instead, government seeks mechanisms for including private enterprise into the planning and financing of protected areas and allowing

the market to plan the spatial location of new protected areas. To this end, governments shape market conditions by instituting biodiversity, carbon, and ecosystem service crediting schemes to allow the market to price and determine the locations of protected areas. This allows this pathway to maximize the instrumental value of nature by focusing protected areas on where they can provide high levels of ecosystem services while minimizing the potential for conflicts with commercial entities, particularly agriculture and forestry. These offsetting programs operate on a global basis, with the state only stepping in to designate protected areas where there are especially valuable habitats with high risk of extinction, which would not otherwise be protected. The KMGBF 30% target is achieved globally with market forces being used to determine the highest marginal utility land on which to locate protected areas. In practice this means that new protected areas are located particularly in the Global South, as this presents the cost-effective solution to meeting the target that requires the lowest amount of overall financing.

Protected areas in Europe and North America are sited the least commercially viable lands in the high latitudes, as well as in locations needed to provide essential ecosystem services. Government enables and design markets for ecosystem services which ensures that these locations necessary for service provision are protected. Through a proper pricing of ecosystem services and negative externalities, the market arrives at the optimum distribution of protected areas to best balance between productive development and securing the ecosystem services which protected areas provide (flood management, pollination, carbon storage, and biodiversity). On a global level too, states and market actors recognize that there is a level of global cooperation and regulation is necessary to ensure that globally important key ecosystems, such as the amazon forest, remain protected in order to avoid global tipping points.

On a landscape scale, protected areas are found on land with low commercial potential. The market does not necessarily seek connectivity between sites as an objective in itself owing to potential conflicts with private property (Naumann et al, 2011), but protected areas still have a moderate level of connectivity as commercial agricultural sites are often synergistically linked up as average farm size grows. In

some region, indices of connectivity are built into biodiversity offsetting and payments of ecosystem services programs (Wood, 2020). Likewise, as the value of nature's contributions to people is increasingly priced and factored into commercial decisions, protected areas and restored nature are located where they are best able to make instrumental contributions and improve people's lives. For instance, new forested areas might be prioritized for flood protection or to manage soil erosion.

Protected areas are rarely strictly no-use zones, and often the sites of high value products, including genetic resources as well as lucrative tourism opportunities for an increasingly wealthy and eco-conscious public. In addition to the fact that they can be lucrative sites of ecosystem services credits, this ability to profit from protected areas allows them to offset some of the opportunity costs to those who live in proximity and manage them. According to the IUCN protected area taxonomy, the focus is on maintaining on sustainable and renewable market access to key resources, with a kernel of targeted non-use protected areas to manage extinction risk and ecosystem service provision. The typical management types in the IUCN taxonomy (IUCN, 2008) are "Managed Resource Protected Areas" and OECMs, with targeted "Habitat/Species Management Areas" for highly vulnerable species or ecosystems.

IPLC are valued as having important knowledge for making accurate assessments of the ecosystem service value of protected areas and are given protections as the best (and often lowest cost) managers of the territories they occupy. In some cases, this leads to a formalization of customary tenure where that is useful to ensure the market can properly compensate IPLC for ecosystem service provision (Naughton, & Sanderson, 1995). As protected areas are focused on provisioning ecosystem services, IPLC management not seen as a major barrier provided that their usage does not conflict with the supply of those services. Compensation for lands lost to protected areas is a calculated on a "willingness to accept" principle (Armstrong, 2024) – i.e., the price as determined by the market value of the land. This maximizes utility by keeping the costs of expanding protected areas low. Public/private conservation initiatives seek to keep overheads low, with some governmental regulation preventing the use of status quo baselines where the status quo is clearly below the

poverty line. Liberal economic/procedural values are maintained by minimizing redistributive governance and allowing conservation companies to make direct agreements with landowners/users to compensate them for their costs.

Protected areas in the EU are located in areas where the ecosystem service and recreational values are high enough to offset their relatively high price. Protection is moderate and focused on ensuring long-term resource sustainability. PAs may be disconnected and allocated to low agricultural value land, such as abandoned farmland. EU supports protected areas abroad through intensification of onshore production leading to less displacement pressure, as well as through a global biodiversity offsetting market. As the biodiversity offset market in this pathway is permissive of companies buying credits abroad, investors and developers in the Global North seek to offset their developments through protecting land in the Global South. Allowing the biodiversity offset market to operate this way allows it to become a vehicle for stimulating north-south capital flows and allowing biodiversity rich developing countries a mechanism for financing conservation and financializing their natural areas.

§4.3.5 Sustainable Consumption:

In this scenario consumption remains higher than other pathways. Instead, this pathway attempts to break the link between consumption, warming, and biodiversity loss through improved technological and systems efficiency, spearheaded by private companies trying to hedge risk and service the demand for ecological products by an increasingly wealthy and eco-conscious global population. New sustainable consumer products and production techniques allow consumption to remain high globally, with consumption rising in the global south and the need for steep changes in lifestyle avoided elsewhere.

A shift to sustainable consumption comes from both supply and demand side. A demand shift for sustainable products, including innovative plant-based products, engineered wood products, and sustainable investment portfolios drives market actors to respond. Consumers demand-side pressure within a competitive market

drives companies to adopt high sustainability standards as a growing global ecologically conscious middle class increasingly "votes with their wallets". Nonetheless, these consumers remain unfavourable to radical shifts in their living standards, ways of life, or habitats. From a mitigation hierarchy perspective, in this future the focus is on the substitution of biodiversity loss causing products with new or alternative products that do not have negative biodiversity impacts, allowing for a transformation without substantial behaviour/lifestyle change or a large reduction in overall consumption.

While demand-side pressure is a major driver in pushing the transition towards sustainable products, so is the desire of businesses to hedge risk and protect themselves against the shocks which would accompany a breakdown in the food and biomass system. Companies actively seek to develop sustainable products and attempt to shift consumer demand towards them. Commercial R&D and marketing play a key role in shaping consumer preference and trying to create products which do not threaten ecological breakdown, but which consumers – especially Global North consumers – also find palatable. In particular agro-businesses seek to push customers onto engineered and novel proteins as the cost of land rises and puts pressure on the expected margins that can be expected from meat products.

As governments take a backseat to markets in this pathway, governments play a very small role in utilizing coercive methods to shape consumption patterns and have comparatively little coercive authority to do so. Likewise, people are sceptical that governments should play a role in telling them how they should live their lives and what they ought to consume. Instead, the state plays a comparatively minor role in incentivizing consumer shifts through nudges, public information campaigns, regulations on labelling, and some moderate pricing of externalities. However, the main cause of the switch to sustainable products is through technology and market competition, bringing prices down and shifting consumer preferences towards sustainable products. There is also a supply side push to get consumers onto sustainable products such as plant-based meats, as the demand side is increasingly bearing of the externality costs of unstainable products which in turn cuts into the profitability of these items.

While the market and consumers are able to drive a switch onto sustainable products, the market puts comparatively lower attention onto mitigating wastage after the point of sale. Corporate responsibility schemes make companies liable for the costs of managing packaging related waste, and this creates an incentive for the market to find ways to minimize unsustainable or unrecyclable packages. However, the market has comparatively little incentive to try to tackle household food waste, and in this pathway this remains comparatively high in comparison with the other paths. Instead, sustainability gains are sought elsewhere in the system. However, some gains can be made here, including through advances in food tech which reduce product spoilage and give it longer shelf and fridge lives. Likewise, there is a niche opened for companies in re-distributing end-of-shelf-life products. Big data and artificial intelligence technologies in supermarkets are also able to improve the efficiency of ordering systems, allowing retailers to minimize losses, and redistribute what remains.

§4.3.6 Bioenergy and Carbon Sequestration:

In order to drive growth and to support a lower reduction in overall consumption, this pathway has a comparatively high energy demand and thus bioenergy with carbon capture and storage (BECCS) is an essential tool for providing energy in a way consistent with meeting climate objectives. Ultimately even in this future though the use of BECCS is moderated by the need to make progress on biodiversity targets, and much of the energy need must be met by a build out of new solar and zero emissions sources. However fossil fuels remain in the energy mix for longer than other pathways, and thus this pathway sees high investment in the negative emissions technologies needed to make the growth focus viable. BECCS is seen as a bridging-technology which can allow full direct air capture technologies to mature. This eventually alleviates some of the land-use pressure that the initial demand for BECCS created.

BECCS is sited where the market deems it effective to do so – i.e., where the price of land and the opportunity costs to developing BECCS instead of productive uses of

the land is outweighed by the pricing of delivering new carbon sinks. BECCS may be sited alongside farmland with due consideration for transport logistics needed to make BECCS carbon negative. In addition to BECCS Enhanced weathering on intensely managed farmlands and forests, and on BECCS plantations – increasing creating co-benefits for biomass production. Innovation and strong market for carbon credits/offsets drives innovation in direct air capture technology with major roll-out by end century reducing need for BECCS. There is a healthy market for carbon credits in order to determine the optimal use of negative emissions, and negative emissions usage rising to meet demand. The market is able to determine the correct balance between forestry/agriculture/BECCS by correctly pricing ecosystem service value of storing carbon.

§4.4 Feasibility

§4.4.2 Actors and Motivations

The key actors driving transformative change in this pathway are organizations of the private sector: corporations/businesses/companies, banks and investment funds, and commercial research organizations. The private sector is both seen as the just means of allocating resources as it allows for a more efficient allocation than government institutions (assumed to be comparatively wasteful), but also as the most likely actor to achieve transformative change within the needed time-scales: owing the phenomenal power that properly calibrated markets and the profit motive have.

These organizations are motivated to achieve positive biodiversity aims for several reasons. Firstly, governing organizations use their power to shape market conditions towards ecological outcomes, though e.g. biodiversity offset markets and carbon markets which raise the costs of degrading nature allowing the market to reach equilibrium. Secondly, they are profit-motivated organizations who seek efficiency gains in order to outcompete their rivals. Thus, they drive innovation into new production techniques and sustainable products, responding to demand for sustainable products. Lastly, businesses increasingly recognize that arresting biodiversity loss and making progress on sustainability goals will be essential for

managing physical and transitional risk and allowing them to continue to profit into the future and avoid stranded assets which are dependent on businesses being able to access the ecologic goods they rely on into the future. Businesses invest into ecosystem services and nature-based solutions in order to secure the 'ecological surplus' on which the entirety of capital accumulation rests upon (Moore 2015).

§4.4.3 Expected Impacts

In this pathway, the focus on market-based mechanisms offers powerful tools to incentivize the reduction in biodiversity loss by integrating the value of nature into economic decision-making. There are three key interventions outlined in this pathway that are intended to have significant positive impacts on biodiversity; payments for ecosystem services, technological advancements, and robust supply chain management.

1. Payments for Ecosystem Services (PES)

PES are financial incentives offered to landowners or communities in exchange for managing their land to provide specific ecological benefits. This can either be done via public financing with direct payments to maintain or restore ecosystems that provide vital services like clean water, carbon sequestration, or pollination. This ensures that public goods, which might not otherwise generate direct revenue for the land manager, are protected. Or via market mechanisms such as biodiversity offsets or credits, where those who negatively impact biodiversity in one area pay for conservation efforts elsewhere to compensate for the loss creating a financial flow from those causing negative impacts to those undertaking conservation.

PES directly incentivizes the conservation and restoration of critical habitats by attaching an economic value to healthy ecosystems, making biodiversity a tangible asset. By providing an alternative and stable income stream, PES effectively reduces the economic pressure on landowners to convert natural habitats into less biodiversity-friendly uses, such as intensive conventional agriculture. Farmers can be paid to maintain hedgerows that provide habitat for pollinators, or forest owners

compensated for preserving old-growth forests that store carbon and support diverse species. This creates a financial motive for individuals and communities to act as stewards of nature, leading to the protection of biodiversity-rich areas and the restoration of degraded ones.

In Uganda, a Global Environment Facility-supported PES project researched the effectiveness of financial incentives for biodiversity conservation outside traditional protected areas on private forests located between the Bugoma and Budongo forest reserves in the Albertine Rift. In this area forests are at risk of clearing for subsistence agriculture and domestic demand for timber and charcoal and threaten chimpanzee and other wildlife populations. Farmers in the project received 70,000 Ugandan shillings (approximately $28) per hectare to maintain trees on their land rather than cutting them down. The results demonstrated a significant positive impact: the project led to a halving of the deforestation rate in participating areas, from 9.1 percent tree loss in the control villages to 4.2 percent tree loss in the treatment villages. However, a follow-up study found that after payments ended deforestation resumed among former PES recipients showing that to be successful PES schemes require long-term financial commitments or a transition to self-sustaining incentives (Jayachandran et al., 2017; Jayachandran et al., 2018).

2. Technological Advancements

Technological advancements contribute to biodiversity protection through two main avenues; natural resource use efficiency and substitution of biodiversity-negative products. Natural resource use efficiency innovations such as precision agriculture use advanced tools, such as GPS, drones, and data analytics, to manage crop production to optimise inputs such as water, fertilizers, and pesticides reducing environmental impact while increasing crop yields (Getahun et al., 2024). Technology, also, facilitates the development and scaling of alternative products that have a significantly lower environmental footprint allowing for the substitution of biodiversity-negative products by consumers. A prime example is the shift from conventional meat production, a major driver of deforestation and habitat loss, to plant-based or cultivated meat alternatives.

Resource use efficiency directly reduces the pressure on natural habitats by lowering the demand for raw materials and minimizing pollution. Compared to extensive monoculture with conventional tillage, where yields can be constrained by soil degradation, erosion, and suboptimal plant health requiring continuous or increasing inputs to maintain baseline productivity, driving conversion of more natural land into agricultural land to meet demand, precision farming and vertical farming (Controlled Environment Agriculture) can reduce the need for agricultural land expansion, preventing habitat conversion, and decrease chemical runoff and water usage that can harm aquatic ecosystems. Precision agriculture can enhance crop yields through better resource management and timely interventions on existing land, drip irrigation can reduce water use compared to traditional flood irrigation, and variable rate application of fertilizer can reduce nitrogen loss (Yost et al., 2017; Farid et al., 2023). Vertical Farming could lead to very high reductions in land use through yields 20-50% higher, or even up to 70% higher year-round, compared to conventional field farming for certain crops (Sowmya et al, 2024). No-till farming, while having varying impacts on yield, dramatically improves soil health and water retention, thus requiring less input for maintaining long-term productivity (Nunes et al., 2018; Chahal et al., 2023).

The substitution of biodiversity-negative products, particularly plant-based alternatives to meat, can have a transformative impact. Livestock farming is a leading cause of deforestation, habitat destruction, and greenhouse gas emissions. A significant shift towards plant-based diets would free up vast areas of land currently used for grazing and feed crops, allowing for reforestation and natural habitat regeneration. This not only directly protects existing biodiversity but also creates opportunities for ecological restoration on a massive scale. If the world shifted towards a predominantly plant-based diet by substituting 50% of animal products, net reduction of forest and natural lands could be stopped (Kozicka et al., 2023) as vegetal products and meat substitutes can have a land use requirement up to 200 times less than extensively farmed ruminants (Nijdam et al., 2012).

3. Supply Chain Management

Supply Chain Management focuses on ensuring that products consumed globally are sourced in an environmentally responsible manner including traceability and certification schemes. Traceability involves tracking raw materials from their origin through every stage of the supply chain to the final product. Technologies like blockchain can enhance transparency and allow consumers and businesses to verify the ecological footprint of their purchases. Certification schemes are independent third-party organizations that set standards for sustainable production (e.g., sustainable forestry, certified palm oil, fair trade). Businesses adhering to these standards can receive a certification label, providing consumers with assurance that the product meets certain environmental and social criteria.

Traceability and certification schemes work by creating market demand for sustainably produced goods, thereby influencing producer behaviour. When consumers demand certified products, it incentivizes companies to adopt more environmentally friendly practices, reducing their biodiversity footprint. Traceability allows for the identification and avoidance of products linked to deforestation, illegal logging, or other destructive practices. Certification schemes, like those for sustainable palm oil or timber, help to prevent the conversion of critical habitats and promote responsible resource management. This empowers consumers to make informed choices that support biodiversity, while also giving businesses a competitive advantage for operating responsibly and minimizing their risks related to unsustainable sourcing. The increased transparency and accountability across supply chains ultimately lead to a reduction in biodiversity loss driven by global consumption patterns.

§4.4.1 Governance and Institutions:

This pathway sees a libertarian reshaping of nation states globally, with states breaking down trade and regulatory barriers allowing goods and services to flow seamlessly around the globe. A key role for national level government is entering into new free-trade agreements that allow for a global restructuring of global food

and biomass value chains, allowing the market new opportunities to find efficiency gains. The government plays an important role in setting market conditions through creating incentive regimes to allow ecosystem services to be priced, and to regulate offsetting regimes. However the expertise of large corporate actors is highly valued and indispensable, and these actors play a key role in facilitating governance.

While government takes a backseat to the market as the major distributive mechanism in this pathway, state and governance institutions still play a role in setting adequate market conditions for driving innovation into biodiversity positive actions. States coordinate region wide biodiversity and carbon offset markets, to utilize the market's powers to spatially plan protected areas. The government plays a role in regulating bad actors and ensuring and enforcing market rules. The utilitarian theory of justice allows the state to play a minimal role in redistributing wealth and goods when doing so needed for optimal welfare outcomes, but overall, the state is prevented from meddling and allowing the market to find optimum cost-effective resource distributions. Governments' main role in the transition is removing the barriers to free trade and innovation needed to allow the technological development and growth needed to break the link between development and biodiversity loss. The government mostly steps back to allow the market to find efficient solutions, intervening to enforce negative environmental externalities being priced into market decisions. Likewise, the government ensures that some progress is being made on social goals, though it prefers to find means of leveraging private actors to do so.

Procedurally government are liberal and democratic, but as the state retreats from economic management there is less democratic control over the economy, and more aspects of life are subject to market forces – such as planning decisions. People are able to exercise their will through consumer choice, and one of the remaining functions of the government is in ensuring competition in the marketplace through a monopolies commission, which ensures that private companies are forced to innovate and make biodiversity positive efficiency gains. A smaller role is directly played by the state meaning that additional recognitional justice gains are made voluntary and dependent on the business practices of private companies. The

predominant way in which people are recognized is as market-actors who make their individual preferences known through their purchasing preferences. Market actors may cater to the recognitional needs of groups or individuals (e.g., local/cultural dietary preferences) to the extent that they are willing and able to pay for them.

In this pathway the EU facilitates free trade between its members, liberalizing its regulatory institutions freeing markets from a degree of constraining regulatory oversight, and negotiating for an expansion of free trade with countries globally. The EU is a technological leader, pioneering new agricultural and ecological restoration techniques, as well as novel products. The government promotes investments into these key sectors using market incentives. There is a robust EU-wide ecosystem services and biodiversity offsetting system, which allows the market to find EU-wide efficiencies in locating agricultural, forestry, and protected area sites. The EU sets the market conditions for these programs to ensure ecological outcomes are achieved.

§4.4.4 Enablers:

This pathway's chief enabler is that it does not predominately rely on behavioural change and a decline in consumption to drive transformative change. Behavioural and value shifts are difficult to enact and steer, and this pathway is able to avoid these to a certain extent by supplanting them with a qualitative shift in agricultural productive techniques and technologies. Consumption remains relatively high and an expansion of green technologies and novel production techniques successfully decouple consumption and growth from ecological damage and biodiversity loss. Likewise, this pathway avoids generating conflict with current powerful actors, through (in part) its limited ambition on environmental of social goals. Agribusiness, private finance, and technology firms are given a central role in governing the transition to a biodiversity positive future and as such their needs are catered for – through a liberalization of international capital movement, limited market regulation, and in places a maintenance of high levels of public subsides. The other side of this is that this pathway does not rely on any novel social or political institutions developing; there is therefore no attendant crisis in legitimacy or delay as new governing institutions coalesce.

§4.4.5 Barriers:

The major barrier to this pathway is the uneven path to development. As there are limited efforts to curb production there is a pressing need to develop novel technologies, products, and production techniques which can enable the growth-biodiversity loss decoupling. The amount of technological innovation required to achieve this is unprecedented and not necessarily guaranteed. This pathway, while improving overall welfare and development, does so unevenly and may even inequality overall. While this is understood to be the cost of progress and compatible with the utilitarian vision of justice, it is a cause of resentment and often resistance. Likewise, as market forces have little incentive to develop demand management, there is a risk of a rebounding effect accompanying efficiency gains (Font Vicano et al, 2018)

The market plays a dominant role in the transition because the state increasingly retreats from acting as an economic manager, except through setting market conditions by pricing externalities. There is a risk that private actors may be able to "capture" the regulatory authorities and set prices for externalities which best enable profitability but weaken environmental protections (Chen & Xu, 2025). The other side of a retreat from democratic control of the economy is a limited ability to make progress on procedural and recognitional justice, as the market has limited incentives to pursue these aims, and there is a lack of authority to compel it to do so.

§5 Global Sustainability Orchestration

§5.1 Overview: Valuation of Nature and Justice Preferences

In this pathway robust global institutions play a leading role in coordinating the transition towards a sustainable and ecological future. In addition to the benefits it brings to people, in this future people value nature intrinsically. Part of recognizing this intrinsic value entails allowing the autonomy of nature to flourish, where natural processes are able to function and develop with little if any human interference (Duran et al, 2022). Indeed, in this pathway the value of nature is understood to be due to its independence from human control (Katz 1991, Taylor 1986, Sessions 1992, Rostrom 1988). In reflection of this, policies are adopted to promote large, interconnected, terrestrial and oceanic wilderness protected areas, where nature is given space to develop and flourish with limited human involvement (Purvis et al 2000, Dinnerstein et al 2019). This is understood not only to be morally obligatory in respect to nature's intrinsic value, but also important, or essential, for securing the ecosystem services needed for humanity (Wilson 2016).

The task of giving back large, interconnected, and highly-protected areas to nature is understood to be a major global challenge that will require unprecedented levels of global transboundary cooperation. Ensuring that this task is managed in a rational manner and in a way consistent with justice, the peoples and states of the Earth are willing to hand over unprecedented political authority to expert-led, global institutions who are tasked with orchestrating the transition in a fair and effective manner. A vast global research effort is devoted to understanding, modelling, and computing the most efficient ways of siting new protected areas while attempting to balance this with minimizing population displacement and the global ability to access critical materials and securing the food supply (Wilhere, 2021).

New forms of political cooperation emerge to coordinate global action between states, built on existing forms such as the U.N. and the E.U. but given increasing power to make top-down decisions to manage the ecological transition. They are

tasked with not only making process on bending the curve on biodiversity loss but also redistributing global wealth and production in order to achieve a prioritarian vision of global justice; focused on directing the benefits to the globally worst off and ensuring that the sustainable development goals are achieved.

§5.2 Justice Preferences

§5.2.1 Distributive

This pathway adopts a prioritarian (Parfit, 1997; Arneson, 2022; Soto, 2024) vision of justice, which emphasizes that all else being equal, benefits should accrue to those who are currently worst off but does not explicitly value equality itself. However, the scope of this prioritarianism is expanded to the nonhuman community too. Facing imminent mass-extinction, it is assessed that the worst off globally are very often non-humans, and thus their preservation is deemed to be a prioritarian necessity. Thus, there is a heavy investment in the development of protected areas, especially for adequately compensating those who are displaced or made worse-off in establishing them (Armstrong 2024).

Prioritarianism is applied to dealings between and within states. Global institutes are tasked with making progress on social goals, and it is agreed that where there are surpluses, they ought to go to those who are globally worst off. Given that today the global poorest are highly spatially correlated with biodiversity (Barrett, Travis, and Dasgupta 2011), this often entails that states are devoting substantial budgets to compensating those who are displaced by new protected areas. Prioritarianism is pursued rather than a stricter egalitarianism because one of the conditions for states submitting to global governance is that the wealthy and powerful states in today's world should avoid the more extensive levelling-down that egalitarianism could require (Porter 2011). Nonetheless, all recognize that some levelling-down in wealthy states is the inevitable price of protecting biodiversity and securing the ecosystem services needed to avoid a worse overall outcome. States in the Global North contribute strongly towards financing the biodiversity transition, as well as making substantial non-monetary contributions, such as reducing their consumption to reduce off-shoring biodiversity loss, as well as onshoring biodiversity harmful

activities, including a greater share of agricultural production and mineral extraction in order to reduce the land use pressure on states in the global south.

A related condition of powerful states contributing is that strict historical responsibility is rejected as a principle for soliciting global financial contributions. Instead, States contribute on an each according to their ability basis. While practically this often means that those with a high historic responsibility do bear the brunt of making financial contributions, states in the tropics make substantial in-kind contributions when they give up expansive areas of their territory to protected areas.

§5.2.2 Procedural

In this pathway decisions political power is moved to higher levels of (international) governance. While these organizations are formally liberal institutions, who reflect the mandates given to them by their member states – in practice decision making authority often rests with a cadre of ecological and economic experts which while they have authority delegated to them by democratic states, are still further removed from and have wider remits than in today's world. These experts are empowered to make science-based decisions which states accept as the best way to manage the transition and solve the collective action problem they each face. People, in recognition of the dangers of ecological collapse, willingly defer to expert decision making in the cases of technical matters (Herzog, 2023).

This system means that there is a relatively low plurality of voices represented, and the average person is often highly removed from the decision-making processes. This is understood as being a necessary trade-off in order to secure cooperation and to effectively mobilize on the timescales needed to address the extinction crisis while simultaneously making progress on social aims (Watson, et al., 2021). While ultimately liberal in character, states often consent to typically illiberal actions (including resource redistribution, and unprecedented international influence in their sovereign territories) because they see the biodiversity crisis as warranting a 'state-of-exception' (Agamben, 2003) where some of the ordinary rules

characterizing liberal government are suspended.

In recognition of nature's intrinsic value, steps are taken to legally incorporating representation of the nonhuman world into political structures (Kymlicka & Donaldson 2012, Dobson 1996, Eckersley 2004). Nonhuman inhabitants of protected areas are understood as having rights to noninterference in their territories, which justifies the exclusive nature of protected areas. They receive a seat at the table in international negotiations, with expert advocates representing them by proxy.

§5.2.3 Recognitional

In this pathway, recognizing that nature has intrinsic (non-instrumental) value, is thought to entail that nature itself can be the proper recipient of justice considerations. In light of this, the scope of justice is expanded, and the "rights" of non-human nature are instituted into legal systems and international agreements. To the extent that nonhumans always were proper claimants of justice, this is great advancement in the breadth of recognitional justice – with these entities being seen and accounted for in moral decision making for the first time.

However, the global scope of the governance structures in this pathway, and the urgency with which they act means that for both humans and nonhumans alike the depth to which they are actively recognized as diverse individuals demanding of respect is often shallow. As people are removed from the centres of power, and decision making is increasingly technocratic, there is little reflection on the full diversity and lives and specificities of those being governed. There is a preference for 'one-size-fits-all' solutions which can overlook diverse epistemologies and ways of thinking.

Nonetheless, the liberal character of the global governance system remains robustly committed to the equality of all before the law and the fraternity of peoples of all nations. People increasingly see themselves as cosmopolitans, or world-citizens who willingly subject themselves to supernational governance (Pogge, 1992) where nation states play a reduced role.

§5.3 Value Chain Segments and Interventions

§5.3.1 Agriculture:

Finding new lands to devote to large and interconnected nature areas puts pressure on areas under cultivation (Mehrabi et al 2018), and thus measures have to be enacted to both increase production per ha in order to make space for a protected area expansion, but also a more egalitarian distribution of food resources globally so that that welfare and poverty targets are met (Balmford et al, 2015). Global governance institutions set centrally designed production targets, coordinate global agricultural trade and exchange, and achieve a sustainable global supply of food to raise consumption in the Global South and eliminate hunger through whole system efficiency gains (Schmidt-Traub et al, 2019). The sustainability concept, as in IMI, is space saving through an intensification of production. However unlike in IMI, this space-saving is achieved through a comparatively moderate increase in yields, a redistribution of those yields to benefit the globally worst off, and through waste and loss reductions through distribution network efficiency gains and a shift to a more sustainable global diet (Eat-Lancet Commission 2019).

This pathway has an intermediate yield increase, with stable yields in OECD and EU with a medium increase in non-OECD owing to a global effort to increase productivity on currently unproductive lands with sustainable mechanization and system efficiency gains. As food prices rise, global coordinated action, including overseas aid and a degree of economic coordination and redistribution is required so as to prevent an increase of nutritional deficiency. As real-world food security is not primarily driven by shortfalls in overall production, the prioritarian outlook of this pathway focusses on redistributing what is produced to those who need it most (Fischer et al 2017). The top-down coordination often focusses on achieving economies of scale at low prices, at the expense of locally diverse and culturally important food systems. Agroecological intensification is achieved through a combination of precision agriculture techniques as well as conservation agriculture (Garbach et al, 2016), especially where the latter can achieve co-benefits by being sited near protected areas or as a means of providing ecosystem services. But overall

agricultural planners take a “consider all options” approach (Royal Society, 2009).

There is a substantial role for new precision agricultural technological innovations in this pathway in order to support an overall increase in yield on a lower land area, but the major thrust of technological development is an expansion of already existing mechanization techniques into regions where they are currently underutilized. States in the global north support transfers of agricultural technologies and help financing for mechanization of agriculture in currently low production regions in order to bridge the mechanization gap. There is a coordinated production of agricultural machinery, and states in the Global North contribute to agricultural development banks which enable producers in the Global South to purchase equipment and improve infrastructure needed to increase yields. This permits moderate labour savings, but through state-led investment into mechanization, the world agricultural system avoids falling into a Lewis trap where falling labour costs disincentivizes capitalists from making productive investments (Dorin et al, 2013). While mechanization does lower the labour requirements of agriculture, instead of a process of urban proletarianization these workers are freed up to be redeployed for ecological restoration work. Mechanization focusses less on high tech precision tools but also on tools required for “sustainable agricultural mechanization” (Sims & Kienzle, 2017) that can be implemented with low-till conservation agriculture. Likewise states direct R&D investment into technologies to support sustainable rice intensification, including mechanical transplanters and direct seeders (SRI-2030, 2023). Big data is collected by farmers, but its ownership is public property. Global experts make use of it to understand were to prioritize investment.

Globally crop production is geared towards provisioning the growing global population while making progress on social aims, including the achievement of a planetary health diet globally. Tempering of market forces and a global shift towards increasing economic planning and command and control mechanisms in agriculture leads to a coordinated effort to ensure a supply of staple foods at affordable prices, and essential nutrients to allow everyone to attain an adequate healthy diet. The global crop mix has a lower component of luxury goods and cash crops, and caters less to the preferences of Global North consumers. The focus is on increasing the

production of plant-based foods, particularly nitrogen fixing legumes, nuts, vegetables, as well as staple grains (Willet et al 2019). Meat and dairy consumption is disincentivized, especially in the Global North as international organizations mandate states to curb overconsumption. Governments globally are not afraid to wield coercive influence and take bold (and unpopular) measures to break the industry power of meat producers and ranchers (Bene, 2022; Fuchs et al 2016). There is a lower emphasis on replacing meat consumption with engineered and novel proteins, which is seen as overly resource intensive for the purpose of placating the tastes of affluent consumers. Rather the focus is on providing plant-based proteins such as legumes. On a landscape scale, farms are large or moderately large which is beneficial to mechanization and supports logistical economies of scale. As farming is less commercialized and farmers are centrally supported by push and pull incentives, farms are at lower risk of going out of business and thus there is not the drive towards very large farms that we see in IMI as commercial agribusinesses buy out small farmers and monopolize their holdings.

The KMGBF 50% Nutrient Loss target is achieved globally. The focus in this pathway is on changing how governments incentivize, and disincentive global fertilizer use to avoid overuse in regions where there is a lack of capacity to absorb nutrient loss, and where possible to increase use in regions where the ecology can support an increase and where doing so can have positive food production outcomes that support the global poorest. The current regime of global subsidies for fertilizer use that vary country to country may be altered, to promote fertilizer use in regions where it is ecologically sustainable and benefits the worst off, and ceasing harmful subsides elsewhere. A global budget for fertilizer use is set, and the remaining budget is reserved for making improvements for the worst off in society. This can occur in two ways. Global fertilizer budgets can be centrally set and then distributed to regions/production systems which are determined to have the greatest need for it. Alternatively, fertilizer-use might be strategically prioritized to ensure a stable and affordable supply of global staples for the overall fertilizer use. The benefits derived from this privileged access to fertilizers are then redistributed to ensure that benefits continue to flow to the worst off. In all cases, the potential benefit to the worst-off people is weighted against environmental considerations and ensuring that

usage only occurs where there is ecological capacity to bear the effects.

A similar system governs the usage of pesticides, herbicide, and other potentially hazardous chemicals. Pesticides remain a feature of agriculture where their usage is necessary to make improvements to the worst off, and where their usage is consistent with the ecological capacity to absorb the impact. Indeed, achieving the agricultural intensification required in this pathway is thought to require a continued use of pesticides, although their impact is somewhat lessened by new technological innovations to less harmful forms.

§5.3.2 Forestry:

In this pathway forestry follows a strategy of intensively managed productive forests to provide essential resources, while saving space for large interconnected intact forest landscapes (Zannotti & Knowles, 2020; Potapov, 2017). Outside of protected areas, the priority for forestry is intensive production. The expansion of protected areas and the attendant pressures of displacement and migration in this pathway creates pressure for an expansion of urban areas to accommodate new residents, and thus a great demand for new construction and building materials. The forestry sector is tasked with providing sustainable materials for meeting this expanded demand, and there is targeted research investment into developing novel engineered timber construction techniques which minimize resource use and contribute to global carbon-storage targets. The overall distributive strategy is expert-led government strategic planning, with cross-border institutions providing expert support and top-down strategic guidance while working with foresters and land-managers to increase production of high-quality forestry products and transitioning certain existing forests to natural and biodiversity friendly forms in regions earmarked as conservation areas. There is a degree of central planning to ensure long-term strategic forestry ends as well as biodiversity benefits through ecosystem connectivity (Keeley et al 2018).

Forestry globally focusses on a combination of productive and protective plantations with a focus on meeting biodiversity objectives. The nature-for-nature valuation leads to forest managers placing a high degree of importance on the naturalness of

plantations and the protection of near virgin and old growth forests is a priority. Another priority is ensuring and promoting the connectedness of forests in order to maximize biodiversity positive outcomes. This means forest managers are tasked with expanding connected areas of native forests, including expanding partly-natural planted forests, and leaving some plantations to revert to unmanaged secondary forests. Government incentivizes the development of plantation-like natural forests in productive spaces where this does not substantially compromise the overall space-saving strategy that prevails outside of protected areas. The focus is on connectivity and strategic landscape planning, but also high intensity plantations to meet biomass needs. Species preservation is a key aim and highly protected forests are sited to prevent vulnerable species extinction. At a landscape scale forest management focuses on achieving ecosystem connectivity to deliver optimum conservation outcomes (Watson et al, 2018). This includes connectivity between conservation and intensive productive forestry, while aiming to minimize space conflict with agriculture. Extensive government support means that foresters have a degree of freedom from market-imperatives to plan forests to achieve strategic resource use and biodiversity objectives.

There is a lower overall supply of forestry products than in the IMI pathway, but instead this pathway focuses on developing long-term sustainable forests, strategic landscape planning, and economic controls to set prices and ensuring provision of high-quality timber products for industry. While in IMI market pressures incentivize fast growing timber plantations, in this pathway the state is able to incentivize a longer-term planning approach. Longer rotation forestry can be practice in the tropics, and in temperate zones forests focus of semi- natural forest intensification. Globally forest distribution is based on balancing social development aims with conservation priorities. Foresters are incentivized to restore quasi-natural forests where conservation needs demand it and there is a focus on strong preservation of existing natural forests, especially where forests contain species at a high extinction risk. There is comparatively more commercial forestry in high latitudes, which allows Europe and North America to onshore production and lower its overseas biomass footprint, which eases the space pressure on highly biodiverse tropical countries seeking land to support development.

Within the EU old growth and natural forests are highly protected, and there is a strong expansion of quasi- natural forestry plantations elsewhere. Forests are large and often interconnected over a landscape, and as the EU is not as strictly bound to achieving high marginal utility as a private profit driven entity is, it can afford to pay a premium to locate forests on higher value lands, when doing so supports its conservation objectives. EU planners aim to increase the EUs self-reliance on lumber produced within its borders as part of its efforts to support development in the Global South by reducing its biomass footprint. By focusing on quasi- natural forestry, plantations and protected woodlands can be interlinked.

§5.3.2 Trade and Intermediate Value Chains:

In this pathway, global trade continues but is highly regulated. The need to attain economies of scale to secure a high enough production to continue to progress on welfare goals means that trade continues to be highly interconnected and global. This is seen as an acceptable trade-off in respect to the fact that short supply chains are often more ecological, as this method of global intensification allows for greater space savings – by ensuring that food is grown where it is most productive and economical to do so. In some areas of the economy, particularly in the global distribution of global staple crops, the market is thought to be an insufficiently rational means for meeting welfare objectives within the highly constrained supply space and cannot be trusted to ensure the progress on welfare goals continues. Therefore, in key sectors of the global economy states and super-state organizations step in to coordinate production and ensure that supplies reach those who are worst off. Global trade is also constrained by the extensive network of protected areas which limit the ability of multi-nationals to access resources in an unconstrained manner. (Global) governing institutions play a larger role in procurement in the food-biomass supply chain to ensure that prices are kept fair and that producers in the global south are able to keep a greater share of the value produced. Nonetheless supply chains remain long to support an intensification of production in the most suitable regions. Government intervention into production and distribution lessens the amount of product differentiation. Price controls limit the profitability of

intermediate value chain actors.

Reducing post-harvest food loss is identified as a major aim of global overseas financing. Global funds are established to allow global south producers to access financing for new equipment and infrastructure improvements. North-south technology transfer is facilitated through a weakening of intellectual property laws on key agricultural technologies, allowing regional production to be established. States establish a global infrastructure investment fund in order to establish adequate storage and transport facilities to eliminate wastage caused by an inefficient global transport network. Global organizations standardize sectoral minimum standards and create international compliance regimes with a focus on legislative simplicity and one-size-fits-all regulations. A central regulatory bureau is instituted to coordinate standard setting and is given broad coercive and incentivization powers to ensure compliance from supply chain actors. Products assessed to be overly harmful and difficult or prohibitively expensive to reform are subject to vice taxes to drive down demand and leverage biodiversity finance. Economic planners aim to achieve global economies of scale to secure a high enough production to continue to progress on welfare goals, which means that trade continues to be highly interconnected and global. In key sectors of the global economy states and super-state organizations step in to coordinate distribution and ensure that supplies reach those who are worst-off and ensure progress is made on social aims.

Finding the resources for the expansion of protected areas (with comparably less attention paid to cost effectiveness) with highly limited economic potential requires an unprecedented global effort. This is especially true as special effort is made to ensure that such an expansion of protected areas does not worsen global inequalities, and indeed the objectives are to make significant progress on global poverty reduction at the same time (as is required by prioritarianism). To square this circle, states recognize the need to contribute a far greater portion of their budgets to benefitting the globally worse off, and especially to compensating those who will have their lives and livelihoods impacted by and expansion of protected areas. Initially, the global community might empower an organization like the World Bank

with the authority to levy finance for debt-for-nature swaps. Global institutions set strong regulations on investment portfolios focused on ensuring transparency and sustainability.

§5.3.3 Protected Areas:

As people come to recognize the intrinsic value of nature, and seek to recognize its rights politically, there is a strong global effort to devote new lands to comparatively strongly protected areas. The KMGBF 30% target is met with comparatively few but expansive areas of highly protected sites, with a focus on locating sites in proximity to each other to form vast interconnected wilderness-esque reserves with relatively low amounts of human activity in comparison with the other pathways. There is a preference for comparatively highly protected sites with relatively minimal human interference such as “Strict Nature Reserve”, “Wilderness area”, and “National Parks” in the IUCN taxonomy (IUCN 2008). This is thought to be a requirement of respecting nature’s intrinsic value, and efforts are made to ensure that natural processes have space to function independently from human management. Similarly individual species are thought to have non-instrumental intrinsic values, and a global consortium of states empower an expert-led body to determine essential locations for protected areas to guard against extinction risk. These regulations are well enforced and there are significant enforceable international treaties governing their management. These impose serious consequences for states who fail to comply with new global protected area regulations. International bodies govern the distribution of new protected areas, monitor their implementation, and carefully regulate their use.

But while protecting the intrinsic value of nature is central to this pathway, there is likewise global recognition that maintaining the functioning of independent natural processes is instrumentally fundamental to the integrity of global ecosystems and supplying humanity with everything that it needs to flourish within planetary boundaries. The KMGBF protected are targets of 30% protected areas met or exceeded globally in scientifically/expert determined conservation value-optimum locations, with some mediation and exemptions are granted to ensure that egregious or uncompensatable burdens are not given to the globally worst off.

The expert-led top-down approach also removes the need for the market to play a role in planning distribution of protected areas. In this future biodiversity offsetting is rejected as a strategy, owing to the fact that in this pathway global institutions are committed to recognizing the intrinsic value of nature. These intrinsic values are seen as grounding ethical obligations and rights of nature, and these act as barriers against nature being seen as fungible and exchangeable. Courts rule that the intrinsic value held by natural places and their inhabitants entail that they cannot be treated as mutually exchangeable for comparable natural places protected elsewhere; and that they must instead be protected in place (Karlsson & Edvardsson Björnberg, 2021).

Agricultural intensification increases the space that can be devoted to protected areas. However, as planning for protected areas is strategically planned by global decision-making authorities who are less concerned with cost effectiveness, the result is a protected areas strategy which prioritizes the best results for biodiversity. Protected areas are large and interconnected with enough space for ecosystem processes to occur with minimal human oversight (Keeley et al 2018). National Park authorities are empowered and given institutional capacity (and funding) needed to effectively plan and implement connectivity between protected areas (Worboys & Lockwood, 2010; Fitzsimons et al, 2013). On a landscape level Protected Areas might try to capture wide areas of the landscape, such as entire river valleys. There is a focus on joining together existing Protected Areas and new restored ecosystems to maximize ecological benefits. In highly forested regions, strictly protected forests might be planned alongside more managed natural-esque forest plantations as this still maintains connectivity. Agriculture that currently exists on valuable conservation land is scheduled to be rewilded.

This strategy of devoting large portions of the Earth's surface to protected areas is thought to raise significant justice challenges, especially owing to the fact that the focus on creating large, protected areas in locations important for conservation overlaps strongly with the current distribution of poverty in the tropics. Therefore, the prioritarian approach to justice represented in this pathway requires significant

global coordination to ensure that the international community avoids the distributing protected areas to locations where they will be most detrimental to the world's worst off. In areas where there is a substantial risk of displacement, a degree of leniency in the strength of the protected areas can be permitted, depending on the relative biodiversity and ecosystem services potential of the region, an expert estimation of its needs, but also sensitivity to the justice claims of the inhabitants (Kopnina et al, 2018). Nonetheless, it is evident that some of the new protected areas will be in locations currently occupied by IPLC and other poor and sub-altern communities and there is therefore a comparatively higher risk of displacements in this pathway owing to stronger protections and a focus on creating interlinkages between Protected Areas. These risks are mediated by a global commitment to protecting IP rights to exist in place, although this does not necessarily attenuate the risk of economic displacements. This risk is borne by those currently on the edges (rather than within) areas scheduled for protection. In the pathway this is understood as being an unfortunate but justifiable trade-off in the face of mounting ecological breakdown and mass extinction.

One of the ways that this pathway tries to minimize the social impacts of new protected areas is through an extensive and generous compensation regime. There is an extensive global effort to raise funds to facilitate the necessary buy-outs to permit an expansion of protected areas, and the fact that PA locations are determined by conservation importance rather than cost effectiveness mean that in general the cost of finding new conservation land is higher than in other pathways. Moreover, the global commitment to achieving prioritarian objectives means that compensation payments are calculated from a moralized baseline based on what occupants ought to be earning if they were earning enough to progress towards meeting global goals of poverty eradication (Armstrong, 2024). The global community commits to setting an anti-poverty baseline to calculate the price offer for the sales. Wealthy nations establish a Global Conservation Bank, which is empowered to purchase debt below market rate for especially debt-laden biodiverse countries based on a prioritarian commitment to raising nations and people out of poverty even when more efficient investments could be achieved elsewhere.

The EU has a few relatively high protection national parks, with the focus on strategic planning to ensure interlinkages and spatial expansiveness needed to allow natural processes to occur with minimum human management. The main way the EU contributes to Protected Areas is by providing funding for Protected Areas abroad, including management and technical expertise and funding for the compensation payments needed to expand global south Protected Areas. The EU also aims to onshore production in order to reduce its displacement of biodiversity loss.

§5.3.4 Sustainable Consumption:

In this pathway global consumption reprioritized to lower the consumption footprint in the Global North to allow space for development in the global south. However, more than just a decrease in over consumption to allow space for consumption to rise elsewhere, there is active redistribution of resources, coordinated by international treaties and government to ensure progress is made on eliminating global poverty. This takes the form of north-south capital redirection via overseas aid and technology transfers needed to ensure progress is made on both halting biodiversity loss while ensuring that social ends are progressed towards. Likewise, there is a focus on minimizing the biodiversity impacts of consumption through efficiency gains which achieved by whole-system economies of scale and the coordinated rationalization of production. From a mitigation hierarchy perspective, this pathway focusses on *reduction* of biodiversity harm from consumption, with coordinated efforts to bring consumption down where it is currently high and shift it to benefitting the globally worst off.

With the high demand for land, substantial efforts to reduce demand, especially in the global north are required. Governments, both global and local, and guided by expert recommendations attempt to shift consumption patterns in a globally sustainable direction (e.g., Lancet Planetary Health Diet), through a mixture of choice architecture shaping and command and control regulation. Whereas in IMI the focus is on pull factors from sustainability minded consumers, in this future governments are willing to use coercive authority in order to “push” consumers towards sustainable choices. Global experts identify a set of ‘sustainable global

diets' consistent with meeting ecological objectives which are widely promoted and incentivized through both "stick" and "carrot" measures. Including but not limited to taxes on luxury and unsustainable consumption such as a "meat tax". States coordinate to set global taxes designed to limit overconsumption, and likewise cooperate to eliminate harmful subsides and other incentives. Doing so also raises the finance needed for new protected areas.

In this world there is a focus on making whole-system efficiency gains to lower the overall consumption footprint. Governments are more comfortable intervening in the private sphere than in other pathways, including intervening in dietary choices, but also in disciplining and regulating consumer and household waste. Taxes and fees are applied to high waste and low re-usability products. Governments also try to create alternatives to wasteful private consumption, such as through "public restaurants" which lower home cooking waste and also redistribute surplus food to benefiting the neediest. Governments set waste reduction targets for retailers and fine them for failing to comply.

§5.3.5 Bioenergy and Carbon Sequestration:

In this pathway climate objectives are met primarily through demand mitigation, a coordinated effort to electrify, improve grid efficiency, cooperation across borders in energy generation and the build out of renewable and other green energy sources including nuclear. Protected areas are sited to ensure that access to the critical minerals required for the energy transition are not compromised.

A moderate use of carbon removals is necessary to offset the emissions of hard-to-abate industries that are necessary for poverty abatement, particularly heavy industries needed to support the energy transition and support infrastructural development in the global south. Nonetheless carbon capture is mostly achieved through non BECSS methods. Afforestation and reforestation play a major role in capturing carbon and increasing the size of the global carbon sink. Ecological restoration including peatland restoration also has a major role to play. Some enhanced weathering may take place on intensive production agricultural regions.

Direct air capture technology is seen as a space saving technology but sees comparatively less investment owing to the high energy costs and is not a major priority. Global agreements limit the use of BECCS to occasions where strategic industries are unable to mitigate emissions. The use of BECCS is continually reviewed to ensure that it does not impact food security or worsen biodiversity loss, and targets for reduction of use are set to ensure that it does not create a perverse incentive against industrial decarbonization.

§5.4 Feasibility

§5.4.1 Actors and Motivations

In this pathway, the key drivers of change come not from a bottom-up value and consumption pattern shift but are instead directed from above by democratic empowered and invigorated global governance systems. These organizations play a number of roles in coordinating the enormous undertaking of directing production towards enabling extensive land-sparing while also making progress on eliminating poverty and other social goals.

A central tension in this pathway is between balancing the self-interests of powerful states who are resistive to regulations which would redistribute their resources, to both the global poor and intrinsically valued nature-itself – the primary beneficiaries. In order to secure cooperation with global governance, some concessions are made to avoid 'levelling down' the lifestyles of those in powerful countries (although all recognize that meeting global land-sharing targets will require substantial shifts in consumption patterns) (Temkin 2000). However, these impulses against cooperation are tempered by a broad recognition that only by submitting to external mediation and coordination could progress be made on preventing ecological breakdown and mass-extinction (Schmitt 1938, Mann & Wainright 2018). The common recognition of this fact drives a (reluctant) willingness from even powerful and wealthy states to accept an effort allocation based on an ability to pay principle.

Likewise, people are committed and motivated to respect the intrinsic value of nature, even where this requires transformative changes in the way political and

economic decisions are made. There is a recognition too that this will require making sacrifices to ensure that the rights of nature a respected. Central to the pathway too is the recognition between all states that no one will benefit if the present-day lack of global coordination prevents each there being a breakdown in the global ecosystem which they all depend on. A key motivator is a shift in value towards recognizing the moral obligations that nature's intrinsic value imposes on us, but also, as the rights of nature are enshrined increasingly in law, states have increasing coercive authority to ensure that it is respected. The global reach of new global organisations gives them wide reaching authority and the ability to ensure that the same regulations are enforceable across borders.

Global institutions are democratically empowered to enforce regulations and prevent free-riders and states disengaging with global agreements. Regulatory agencies set global standards for production and impact reporting and are able to bring corporate entities in line and direct their activities towards meeting global goals. Governments and International organizations, with expert assistance and advice, set country by country consumption targets which are achieved through a mix of regulation and expanding social awareness. Research efforts are pooled and directed in line with internationally set priorities – particularly for scaling up productive technologies, technologies needed for new urban living, and generating the knowledge needed to assess the socio-ecological impacts of new protected areas.

§5.4.2 Expected Impacts.

Global governance refers to the multifaceted system of international laws, conventions, institutions, and norms through which states, international organizations, and non-state actors collectively address environmental challenges that transcend national boundaries. In this pathway this intricate institutional architecture is seen as fundamental to achieving a delicate balance between social and environmental objectives. Through strengthening the current global governance system, it is assumed that it would positively impact biodiversity through; 1. Enforcing global environmental standards in agriculture, 2. Creating equitable food systems to reduce food loss and waste, 3. Reforming environmentally harmful

subsidies, 4. Providing greater levels of protection and increasing incentives for protected areas.

1. Enforcing global environmental standards in agriculture

Despite the number of international frameworks and national regulations, a truly universal and consistently enforced global environmental standard for agriculture does not exist and indicates a persistent "regulatory gap" where national sovereignty, diverse economic priorities, and varying levels of development often lead to fragmented or inconsistent application of standards. When effectively enforced, global environmental standards can significantly curtail environmentally damaging agricultural practices and lead to improved soil health, higher carbon storage and increased biodiversity (Gomiero et al., 2011; Smith et al., 2019). Enforcement actions, which can range from routine inspections and warning letters to substantial fines and even criminal prosecution, serve as a crucial deterrent to non-compliance and help maintain a fair competitive environment among agricultural businesses.

2. Creating equitable food systems to reduce food loss and waste

Equitable food systems seek to systematically dismantle structural barriers to fair food access, transitioning from a system driven by socioeconomic factors to one guided by principles of fairness and justice. This approach directly addresses critical issues such as poverty, income inequality, and geographic barriers that limit access to nutritious food and is aligned with broader SDGs focused on ending hunger and promoting gender equality. And at the same time, can produce more sustainable food systems by tackling issues such as food loss and waste. Reducing food loss and waste yields substantial environmental benefits: it conserves vital resources such as land, water, energy, and labour that are otherwise squandered. It significantly reduces greenhouse gas (GHG) emissions, as 8% of global emissions are attributable to food loss and waste (Scialabba, 2015) and the EAT-Lancet Commission estimated that reducing food loss and waste by 50% could reduce biodiversity losses by up to 33 percent relative to its business-as-usual scenario (Willett et al., 2019).

3. Reforming environmentally harmful subsidies (EHS)

In 2024, an estimated $2.6 trillion was spent on EHS, equivalent to 2.5% of global GDP, and this estimate has increased by $800 billion since 2022, indicating a worsening trend (Koplow & Steenblik, 2024). Specific impacts of these subsidies include agriculture subsidies being responsible for 14% of global deforestation (amounting to 2.2 million hectares annually) and fisheries subsidies (over $35 billion annually) leading to dwindling fish stocks and the proliferation of oversized fishing fleets (Damania et al., 2023). Beyond direct environmental damage, EHS distort market prices, misallocate resources and investment decisions, create unfair competition, ultimately hindering stakeholders from making nature positive investments.

Organizations like IISD have proactively outlined steps governments could undertake for successful reform offering practical tools and methodologies for repurposing harmful subsidies (Gerasimchuk et al., 2025). Repurposing EHS presents a clear opportunity for transforming food and biomass value chains. Redirecting even a fraction of the $2.6 trillion currently spent annually could vastly increase funding available for nature and climate solutions. Sustainable agriculture subsidies, for instance, could provide essential financial support to farmers to adopt environmentally friendly practices, helping to offset the initial costs associated with transitioning to sustainable methods and encouraging the adoption of new, beneficial technologies. These positive incentives could lead to a range of environmental benefits, including improved soil health, increased biodiversity, reduced greenhouse gas emissions, and enhanced ecosystem services (Gomiero et al., 2011; Smith et al.,2019).

4. Providing greater levels of protection and increasing incentives for protected areas

The Kunming-Montreal Global Biodiversity Framework (GBF) stands as the central international instrument for protected areas, with its ambitious Target 3 aiming to effectively conserve and manage at least 30% of terrestrial, inland water, coastal,

and marine areas by 2030. Target 3 of the GBF explicitly emphasizes that protected areas and OECMs must be effectively conserved and managed with the primary objective of achieving positive biodiversity outcomes. This necessitates that these areas are ecologically representative (encompassing a comprehensive range of existing ecosystems and ecological processes) and well-connected through corridors, forming cohesive networks capable of sustaining in situ conservation and adapting to environmental stresses, including the impacts of climate change. Due to issues such insufficient technical and institutional capacity and ineffective or inappropriate policy frameworks currently large areas of protected areas are poorly managed, lack ecological representation, or are disconnected from wider landscapes so will fail to deliver the desired biodiversity outcomes (Leverington et al., 2010). Global governance in this pathway would therefore evolve its focus from a purely quantitative metric to a more robust qualitative assessment, emphasizing the implementation of sound management plans, ensuring ecological connectivity, and securing adequate resources for protected areas to create greater positive impact.

To support this greater protection global governance plays a pivotal role in facilitating financial mechanisms essential for biodiversity conservation. Financial initiatives such as the Global Environment Facility's (GEF) funding has led to the creation or improved management of over 1,600 protected areas, encompassing 360 million hectares, and has enhanced the sustainable use and management of biodiversity across more than 100 million hectares of productive landscapes. Overall, the GEF has invested over $5.2 billion, which has successfully leveraged an additional $13.4 billion in co-financing, supporting 1,500 projects in over 158 countries worldwide (World Bank, 2008). Increases in fiscal transfers to countries that would otherwise develop areas for social objectives would have a positive impact on overall levels of protected areas with the resulting environmental benefits.

§5.4.3 Governance and Institutions:

Supernational organizations - including the U.N. as well as novel institutions - play an increased role in governing the transition. Biodiversity is understood to be a global issue requiring global governance, and states recognize that managing a transition

to a biodiversity positive future while making progress on global social development goals (including poverty eradication) will require unprecedent levels of international global cooperation. States come together to empower new global governing bodies and institutions which have substantial powers to coordinate action including managing affairs usually left to states themselves.

The coordination challenge posed by expanding space devoted to protected areas is recognized and states commit to developing supernational institutions which are empowered to orchestrate change. Governance in these organizations is technocratic, and concessions have to be made to powerful states in order to guarantee their involvement. Some levels of present-day consumption are grandfathered in, and following the lessons of the Kyoto protocol, questions of historical responsibility are minimised in order to bring powerful states in today's world onside with increased global governance. Nonetheless, power states have to accept that some transfers of capital and reductions of consumption have to occur within their polities in order to make progress on achieving a prioritarian vision of justice and to halt biodiversity loss.

Governing actors play a major role in coordinating transition efforts through expert-led command and control policies. The government has strong enforcement powers which are coordinated across borders. Global governing institutions rely on the expert advice of coordinating boards of scientists and economists to make planning decisions and ensure that actions taken are done in a way which maximizes positive outcomes for biodiversity and the globally worst off. Upscaling governance to global actors is a major coordination challenge, and individual citizens are now further removed from important decisionmaking power. While global institutions are democratic, authority is increasingly devolved. Global institutions increasingly rely on experts to make decisions and there is a weakened role for public consultation – something thought to be too challenging at a global scale, and also an impediment to taking swift and decisive action

The international order and associated global governance institutions are liberal in outlook and willing to exert coercive authority to enforce human rights and

international law. States see the most practical way of enacting prioritarianism is through liberal internationalism, and a formal respect for global human rights. However, this may overlook the specific needs of subaltern groups in the pursuit of formal liberal equality before the law. Governments also commit to recognizing the rights of nature and find novel means of representing these in liberal government institutions. The recognition of nature's intrinsic value means that in this pathway governance organizations are obligated to incorporate consideration of nature into political and legal processes. The liberal instincts of governments in this pathway tends to render these as 'rights' which are held against human society – hence the need for exclusionary protected areas to some extent. (Kymlicka & Donaldson, 2012). Public advocates for nature/species/natural areas are appointed who receive a seat at the table in international negotiations.

The EU plays a global role in coordinating the ecological transition, using its governmental, bureaucratic, and scientific-technical expertise to play a central role in the design and implementation of new supernation governmental bodies. The EU acts as a model for how a successful system of regional multi-national coordination can be implemented, and EU planners and policy makers have key skills to be shared in designing new cross-border cooperation efforts globally. The EU government facilitates the transfer of finance and technology to support biodiversity positive actions globally, including onshoring of production to reduce its global ecological footprint. It acts a strategic ecological planner and takes on new responsibilities and centralized authority to let it play an active role in coordinating and redistributing production

§5.4.4 Enablers:

Institutions that facilitate transformative change in this pathway already exist but would need substantial strengthening of their mandate in order to achieve transformative change. Likewise, unlike Local Commons Stewardship, this pathway can expect to make efficiency gains through leveraging economies of scale, as production is globalized. Unlike in IMI where the market drives efficiency and specialization, this pathway aims for one-sized-fits all, "good enough" solutions

which can be mobilized quickly and shared worldwide. Global institutions are able to coordinate productive capacity to avoid wasteful competition.

§5.5.5 Barriers:

The chief difficulty in this pathway will be securing the degrees of international cooperation needed to make the global cooperation that drives transformative change possible. We know that from the history of the Kyoto and Paris agreements, states are often unwilling to commit to international cooperation, even when such cooperation is in their long-term benefit, if it costs them to do so. While this pathway does give some grandfathering concessions to the wealthy and powerful states of this world, it still requires them to make very substantial contributions to financing the vast program of transition measures. All states too will be required to give up degrees of sovereignty to decisions made in super-national organizations and will be asked to make land-use changes which will often be detrimental to their near-term interests- particularly giving up land to non-development protected areas.

In addition to resistance from states, this pathway may also face resistance from business and corporate actors who fear the levels of global regulation and constraint of markets which this pathway requires. Some very large corporations may be able to successfully infiltrate the establishment (regulatory capture), either as a concession or in order to leverage their supply chain and organization knowledge, or to speed up the transition by relying on existing structures rather than relying on building entirely from scratch.

Likewise, this pathway intends to meet its environmental goals through an expansion of protected areas, which puts increasing pressure on vulnerable communities at risk of being displaced. While this pathway devotes extensive resources to compensating those who are affected by protected area expansions it can still expect resistance from displaced and affected communities.

Moreover, this pathway is committed to recognizing the intrinsic value of nature. This is a major political challenge and requires changes to both legal and political

systems to ensure that the inherent moral worth of the nonhuman world is adequately safeguarded. Ensuring that the rights of nature are respected in practice means that at least occasionally political and legal decisions will be made which are unfavourable to human persons, and in this pathway, states will be using their coercive authority to ensure that the decisions are respected. There is a risk that this could cause resentment from people and communities who are forced to make concessions for nature, or who do not recognize nature's intrinsic value. This may lead to conflicts, resentment, and resistance to environmental policies being enacted and enforced.

§6 Local Commons Stewardship

§6.1 Overview: Valuation of Nature and Justice Preferences

In this pathway the world develops according to strongly communitarian beliefs, which emphasize equality and solidarity as the chief virtues of political life. There is a broad rejection of individualistic ethical views, in favour of a conception of politics built around serving a 'common-good' (Kymlika, 1993/1996). Communitarian accounts of political theory emphasize relationships between community members and a shared way-of-life rather than the atomistic well-being of their individual components. However, in this pathway this understanding of common-good is extended beyond the human based on a strongly relational connection to their bioregions and the species they co-habit with (Plumwood, 1993; List, 1993; Bookchin, 2007; Ghijselinck, 2023). The communitarian character of this pathway entails a focus on maintaining functional community relationships as a key political virtue. However, these communities extend their notion of community membership beyond their human compatriots and extend it to the nonhuman living and non-living areas they cohabit their regions with. The 'common-good' for each more-than-human community is understood as the maintenance of the diverse nature-culture interactions which each society has with its local environment, as well as fostering new harmonious ways of living-in and living-as nature, based on mutual respect, solidarity, and a rejection of the domination of nature.

Each region and community seeks its own pathway to ensuring flourishing nature-connected relationships, often by drawing on and reconnecting with local indigenous knowledge and traditions. In some places, entirely new habits emerge that promote sustainable and solidaristic relations between humanity and nature. In general, this focus on close cultural relationships with nature leads to a world where land is used extensively with minimal areas devoid of human activity and a strong social connection and geographical proximity between producers and consumers. Likewise, the strong community/solidarity-oriented values lead to a distributive emphasis on equality between community members. Local community members democratically organize production in a way to best meet their community need and share resources amongst themselves equally. Communities often govern their resources as commons to ensure equitable access to resources and distribution of benefits (Ostrom, 1990). Their solidarity with their local bioregion leads them to voluntarily set limits on consumption in order to reduce their impact on their local environment, with the halting and reversing of the loss of both local bio-cultural diversity and local biodiversity perceived as an important goal. Likewise, communities pursue policies of onshoring production and reducing their dependence on overseas trade to satisfy needs which could be met through local production. This is motivated not only by a preference for consumer products which also satisfy cultural needs (which could not be met by imports from abroad) but also a desire from consumers to be able to ensure the quality of the goods produced by having close relationships between producers and consumers. Overseas exchanges still exist, especially in regions where they are necessary for meeting basic needs. But in these occasions communities seek to make links with culturally connected but distant communities, seek mutually beneficial relationships, and form trading partnerships based on shared ethical values.

§6.2 Justice Preferences

§6.2.1 Distributive

This pathway represents an egalitarian distributive preference (Arneson, 1989; Cohen, 1989 & 1990; van Parijs, 1995; Lippert-Rasmussen, 2016, Armstrong, 2024) &

limitarian (Robeyns, 2019). Societies recognize that further pursuit of economic growth cannot be reconciled with meeting environmental aims; and seek to best distribute the wealth, resource, and material goods which have already been produced as equally as possible. This pathway is defined by a return to a localized, community driven account of politics and envisions a reduced role for markets in the distribution of goods. Instead, in this pathway the world adopts "post-growth" or "degrowth" economic thinking (Fioramonti, 2017a; Schneider, Kallis & Martinez-Alier, 2010), deprioritizing the pursuit of economic growth over the pursuit of socioeconomic and environmental goals. The local communitarianism in this pathway is a means of facilitating to a greater degree the democratization of the economy, where production decisions are made based on a calculation of their use-values for meeting the needs of the local community, rather than on an estimation of their exchange values as commodities. Because societies are aiming to primarily meet the needs of their local communities, the comparative efficiency loss of economies of scale is compensated for by local, customized and artisanal production, with lower capital (and in the case of agriculture) chemical inputs (Bunori et al, 2016, Fioramonti, 2017a).

While this pathway aims for an egalitarian outcome, seeking to redistribute resources as far as possible in accordance with *need*, this general egalitarianism is tempered by a recognition of differentiated responsibilities including a recognition of the historic role that some states have played in driving inequality globally – through over-use of global common resources (taking more than their fair share and not leaving enough for others), but also through the historic role colonialism and neo-colonialism have played in perpetrating economic underdevelopment in the global south. Societies recognize that a commitment to egalitarian entails corrective justice obligations, to actively redistribute wealth from the global north to the global south. To this extent, on a global perspective this pathway is *limitarian* – the focus is on setting upper limits to consumption which cannot be justly exceeded (Robeyns, 2019; Rockstrom, 2023).

§6.2.2 Procedural

In this pathway the devolution of power to small local communities is a facilitator of

directly democratic processes. Societies involve democracy in a wider range of aspect of their lives – including in decisions over production priorities and the fair sharing of resources within communities. Communities set locally specific rules over how the land is to be used and shared, and collectively decide what an appropriate use of their resources is in order to best promote their chosen life-way in accordance with their cultural appreciation of nature (Ostrom, 1990; Bookchin, 2007). Land is increasingly owned in common, which facilitates increased public deliberation over how this land can be used.

The devolution of power away from centralized government institutions means that there is a reduction in the forms of coercion that can be levelled against dissent. The changes in decision making infrastructure occasionally mean that social stigmatization and other informal means of pressuring those who do not share community values are employed. Likewise, these institutions are vulnerable to organized blocking tactics. Reliance on persuasion and consensus mean that societies can be slow to respond.

Globally, governance is highly polycentric. Communities have a great deal of devolved power but agree to coordinate and cooperate on pressing transboundary issues, including over biodiversity conservation and preservation Likewise states cooperate to ensure a limited system of international trade to ensure that basic needs can be met globally. States ensure that trade deals are made with fairness for both parties in mind, and that the agreements made should help both communities progress towards more equitable outcomes for their communities. States are driven and motivated by being 'moral leaders' and prefer to lead by virtue and example rather than through global coercive mechanisms. This leaves limited options that can be employed against non-cooperative states, other than sidelining them on trade and attempting to persuade with moral force.

§6.2.3 Recognitional

The egalitarian account of justice in this pathway is not limited to equalising distributive outcomes but also extends to fostering egalitarian social relationships

between members of a society (Lippert-Rasmussen, 2016; Fraser & Honneth, 2003; Axelsen & Nielsen 2020) that inherently value and respect social heterogeneity and seek to ensure that social difference is not a source of outcome differentiation. This pathway focusses on making environmental gains by allowing local communities to find solutions which work for them, which accord with their cultural and spiritual values. By necessity this involves recognizing as legitimate a plethora of different ways of living, local knowledges, and cultural preferences. This is specifically enabled by the local levels of governance this pathway demands, as recognizing a broader range of perspectives enacts organizational costs which multinational governance cannot bear. The focus on finding new, and resurrecting sub-altern, ways of co-existing with nature leads to a valorisation of IPLC knowledges and social systems (Whyte, 2011). The devolution of power gives IPLC a greater opportunity to take charge of their own affairs and govern their own communities.

§6.3 Value Chain Segments and Interventions

§6.3.1 Agriculture:

In this pathway agriculture shifts toward extensive low-input organic, heritage, and agro-ecological methods. While having a comparatively low yield and therefore requiring a greater share of terrestrial space have very low impact on biodiversity (Agnoletti & Santoro, 2022; Koohafkan & Altieri, 2016). The precise form of low-intensity production system varies region to region as people look to traditional and regionally specific forms of agricultural production and discover new ones which suit their community needs. These production methods give people a living link with the past, and being labour intensive, they bring greater numbers of people back onto the land and directly into contact with nature-positive farming. Farm sizes are typically small and in close proximity with flourishing rural settlements, and nestled within forests and semi-natural lands. As the farming systems are comparatively labour intensive and (in comparison with the other pathways) non-mechanised, small farm size has less disadvantages. Farms are bordered with rich hedges and insectary strips to support pollination and promote local wildlife. As communities switch to a post-growth and needs based economic structure, large farms are increasingly turned over to commonages to be used for the benefit of all. People often have close personal

contact with their agricultural regions, either work them themselves or know those who do through short supply chains which put them directly in touch with growers.

While not all non-conventional land management systems are necessarily lower yield (Rodriguez et al, 2024) there is still a role played for sustainable intensification too, including precision farming techniques – especially where space is at a premium. But in comparison to the other pathways, these techniques play a comparatively minor role. As this pathway sees an increase in low productive systems, it sees the overall lowest yields. Yields remain stable or decrease in OECD countries, and yield growth has the lowest growth in non-OECD. A wider range of crops, including heritage and climate resilient breeds (Doggalli & Srivastava, 2024), are grown to substitute for chemical inputs and increase local autonomy of agricultural value chains, and societies share knowledge to identify the best techniques and cultivars to suit local conditions. As communities switch away from a profit-driven agricultural system, these varieties become more viable as an option for farmers, who can now manage farms for provisioning to local tastes and supporting ecological restoration on their land rather than focusing on maximizing market value. Input use is reduced by both an extensification of practices and a reduction in production. Societies reduce their consumption (e.g., towards a planetary health diet) and share what is produced on a more equal basis to reduce demand, thereby accounting for a lower yield farming system.

Restoration targets are achieved mainly through restoration on-farm rather than taking areas out of production. Agricultural land is interspersed in a mosaic of semi-natural elements including ponds, woodlands, forests and scrubland in order to support ecosystem services. The shift to low input agricultural production increases the reliance of food production on securing ecosystem services, especially pollination services. Therefore, protected areas and semi-natural land is spatially distributed throughout agricultural regions to ensure that farms are adequately provisioned and all people receive equal access to nature's benefits. There is a high on-farm species diversity.

A central dynamic in this pathway for farmers and farming communities is resisting

rural dispossession and ensuring the viability of rural and farming communities to continue practicing their traditions and to remain on the land which they have strong cultural and relational ties to (Li, 2010; Peters, 2013; Bernstein, 2004). Communities seek protections against a further expansion of industrial farming and are resistive to processes of further mechanisation as these create a structural pressure to move people off the land through lowering labour requirements. The shift to a labour intensive low-input farming system is seen as essential for ensuring that rural communities continue to exist and play a role as key actors in the economy. Local communities are strongly resistive to the idea of a depopulated rural "farms-without-farmers" (Senthold & Asche, 2019) and therefore see a synergy between advocating for their own equality and rights and adopting more ecological farming techniques. New technological improvements in farming systems are focused on artisanal mechanization designed to meet very specific local needs, as well as "appropriate technologies". Regions in the Global North support agriculture in the Global South through technology and knowledge transfers, and this is seen as complimentary to the local ecological knowledge of IPLCs in those regions.

In this pathway there is a changing relationship with meat production. The shift to low-input farming techniques with a low reliance on the chemicals industry and a decentralization of production means that globally herd animals are maintained as they are needed to produce fertilizer. Likewise, meat production remains central to the dietary cultures of many communities globally, and some production of animals for meet is needed to meet this cultural need for animal protein. But nonetheless there is a different discourse around the consumption of animals, owing to a common recognition that overall consumption globally needs to drop in order to achieve key sustainability goals. New meat consumption cultures develop, and while these are diverse globally, they are in general focused on producing low volumes of high-quality meat. Meat is a prized commodity, eaten rarely, and is often produced with short supply chains between producers and consumers, allowing consumers to have a closer cultural connection with the meat that they are consuming and giving them a vested interest in ensuring it was produced to high ethical and environmental standards.

Nutrient-loss is minimized through a global transition to a labour-intensive organic farming regime (Kirchmann & Bergstrom, 2001). Organic agriculture refrains from using synthetic fertilizers and pesticides, promotes crop rotations and focuses on soil fertility and closed nutrient cycles. A global shift to organic and low till agricultural systems successfully reduces nutrient loss from farms. A patchwork agricultural landscape interspersed with forests and wetlands plays a role in capturing and sequestering nutrient runoff from farms. The KMGBF 50% target is achieved region to region, with some bilateral trading between regions to support progress on global equality. This pathway has the lowest artificial fertilizer use globally owing to its shift to low input farming, and through the fact that mixed farming systems with crops and livestock are able to self-source organic fertilizer. However, even under a global shift to organic and allied forms of sustainable agricultural systems, there is still some need for artificial fertilizer use globally (Conner, 2008). Within communities, farmers deliberate over equitable ways to share their share of a globally sustainable level of fertilizer use, for instance on an egalitarian/ needs-based basis – either per hectare, per capita, or distributed to the most effective uses and the final products of which are distributed fairly. There may be unequal uses of fertilizer globally between the regions – with different regions consuming more or less depending on agricultural conditions or needs to meet a local dietary specificity; but there is a commitment from the highest overuse regions to cut usage most dramatically.

§6.3.2 Forestry:

In this future forestry focuses on developing lower biodiversity impact extensive production systems. Forestry is a component of expansive mixed-management landscapes, featuring a mosaic of quasi-natural productive forests, farming, and light-touch protected areas and restoration land. Traditional low impact methods of forestry are practiced with a focus on supplying high value, culturally fulfilling products, as well as aesthetic goods to those who live close to the forests they manage (Erickson et al 2002). A global shortening of supply chains means that communities often rely on locally produced forestry products for a wider range of uses than they do today, as forestry products become an important substitute for

other unstainable consumer and industrial products. However, this widening of uses that forestry is put to does not stimulate a great expansion of forest, instead and overall demand reduction and extensive recycling of materials limits the extent to which this changes the overall total of global forestry cover. Forests are restored on currently managed lands, and on a landscape scale farms and forests forms an expansive patchwork/mosaic.

Forest managers have a preference for native-species combined objective forestry; which can support biodiversity, ecosystems services, and cultural services. Currently existing intensively managed plantations are restored to form mostly-natural medium or low/close- to-nature forestry as overall demand/consumption lowers. There is an effort to ensure that exotic species removed to support culturally significant species and ecotypes. Foresters aim to produce high-quality value-added products to support the needs of their local communities, and consequently there is regional variation over forest uses and product types. There is a significant community autonomy in distributing the placement of forest, and communities do so according to locally specific and culturally derived goals. Additionally, communities recognize the important role the ecosystem services provided by well-managed forests plays in supporting expansive low-impact organic agriculture, including through the management of water quality, flood regulation, and particularly supporting wild pollinators. The shift to a community-led needs-based economy means there is scope for a significant role for non-market factors in deciding forest location.

. Management is typically low intensity logging within extensive semi-natural forests, although the exact management regime depends heavily on the forest type, composition, and the kinds of uses that communities put their forests too. In addition to timber production, communities may begin silvicultural food production which reduces agricultural conflict. Forests are also a valued cultural and recreational resource with high visitation rates and amenity values. Globally too the shift to short supply lines lead to an extensive distribution of forests globally, with a comparatively low focus on connectivity and creating wild forests, except where high non-use protection is essential for ensuring ecosystem service provision or to preserve

keystone species. Foresters and forest communities are globally respected for their skills and traditional knowledge for sustainable forest management.

Within the EU, imports of foreign wood products decline sharply as these are replaced with locally produced alternatives, albeit with a higher price tag which drives down demand. Within continental Europe plantations of exotic species are gradually phases out to be replaced with long rotation native broadleaf woodlands and pines. Forestry is multi-functional and communities rediscover traditional ways of managing their forests to provide a variety of different products which vary region to region. There is extensive forestry in the high latitudes with populous communities in the region working rewarding jobs. The low intensity of management reduces the need for strict protections of forests which are no longer threatened by commercial imperatives towards overuse. People regularly visit their local forests, can name their local species, and increasingly use products sourced locally.

§6.3.3 Trade and Intermediate Value Chains:

While communities shorten supply chains and produce a greater amount of the resources they need locally, global trade still occurs. Communities act as ethical consumers and prefer to import and export goods to communities who are aligned with their ethical and cultural values and standards – and this drives an upward momentum for protections and lower impact production methods in order for suppliers to access markets. In practice this may develop in a similar way to an EUDR-like mechanism, where communities try to ensure their preferred environmental and ethical production standards are upheld by their trading partners. This is driven by the strong ethical values of consumers in this pathway and the high importance they place on their culture values and preferences, wishing to see them shared globally. This creates barriers to frictionless global trade, but enables communities to live by their ethical standards.

Post-harvest food loss is reduced substantially owing to a shortening of supply lines and close to harvest consumption. Likewise, there is a shift in food-culture away from needing perfectly regulated and standardized produce for retail. There are less

middle-men in the supply chain, with people often getting the food through an agricultural cooperative or from farmers themselves at local farmers-markets; and they are happy with "wonky" produce which modern supermarkets would be unwilling to accept. The shift to organic and low pesticide production does lead to a modest increase in on-farm loss, as more of the harvest is lost to pests, and especially if high labour needs go unmet.

Within regions, themselves novel means of sharing resources are developed in order to promote equality; these include community kitchens and food hubs. Governments are focus on incentivizing "farm-to-fork" distribution networks with increased connectivity between producers and consumers, with their aim of cutting out intermediate market actors and profiteering. Food is consumed locally and seasonably and every town has a vibrant farmers market to facilitate the flow of local agricultural products. This promotes local cultures and breaks down rural urban divides by making direct connections between producers and consumers. People also feel connected with their local environment, understanding the cycle of the harvests and feeling proud of what their bio-community is able to produce. There is a limited global trade for essential goods, owing to the fact that communities are increasingly focused on developing self-reliance and producing what they need for themselves – though no community is an island unto itself. Some communities still pursue export-led development strategies and simply owing to the global distribution of populations and productive regions there cannot be a full regional autarky. Global trade is restructured away from the current system of global free trade and operates on a peer-to-peer basis with communities of producers and consumers preferring to make bi-lateral links with trusted and value-aligned partners. There is comparatively limited global trade in this pathway as production is increasingly on-shored, owing to a consumer preference for locally produced goods. This shift to a needs-based economy means that markets are less relied on for distribution within regions. The global exchange of goods continues for essential products that cannot be produced locally, which is organized on a bi-lateral basis.

The devolution of political authority in this pathway means that communities and regions are given increased autonomy to decide how to regulate their activities; and

they use this to adopt environmental and ethical production standards that are fitting and appropriate to their values and particular ecological settings. Protected product origin designations are used to ensure that foods and resources are from genuinely local sources and that the products meet the high expectations of local communities. There is comparatively little standardization between regions which acts as a barrier to easy trade and creates pressure for local production.

Locally, the move away from market-distribution towards a 'needs based' economy comes with a transition in the forms of financial actors which exists. Global investment banks are sidelined in favour of community credit unions, cooperatives, and building societies, which act as functionaries for moving money locally in a way which is more sensitive to local conditions and contributes towards circular economics. Globally, however, the recognition of historic responsibilities means that novel financial institutions are set up to facilitate north-south capital flows. Communities voluntarily commit surpluses to a loss-and-damages fund. Communities try to identify bilateral means of compensating states in the tropics for the opportunity costs of biodiversity protection (although in this pathway there are minimal restrictive protected areas). Communities commit to the free sharing of technology and expertise. There are widespread debt cancellations, occasionally with biodiversity conservation conditionalities.

§6.3.4 Protected Areas:

In this pathway the KMGBF 30% protected area target is shared equally between nations/communities on a per-capita basis, with some Global North countries taking on additional burdens in respect for global equality and historical responsibility. Strongly protected areas have very limited uses in this pathway, excepting in scenarios where the biodiversity is too vulnerable to disturbance to permit even the lowest impact agricultural or forestry uses. Sometimes these areas are understood as being global commons (as Antarctica is today), and in recognition of this there are global commitments to protect them and compensate those who live in the region for the opportunity costs which come with strict non-use (Armstrong, 2024). Other states have cultural preferences for wilderness areas and may choose to delegate

and manage protected areas in this fashion. However, the preference for extensive agricultural use and culturally significant low impact product acts as a soft barrier to the expansion of exclusionary or fortress conservation projects. Instead, this pathway focusses on achieving cultural goods through the management of its protected areas.

On a landscape scale, the transition to extensive low-impact forestry and farming leaves comparatively reduced spaces for strictly protected areas, and the use of these is limited to protected only the most vulnerable to disturbance habitats. Protected areas tend to be either National Parks, or Protected Landscape/Seascape in the IUCN typology (IUCN, 2008), plus a large component of the 30% target is achieved through OECMs that allow people to continue living and working in protected areas. Protected areas are understood to be a way that communities can promote and foster positive human-nature relationships, and are located with a focus on preserving culturally significant landscapes and emblematic species/ecotypes. The strategy of extensive low-impact productive regions breaks down the productive/protected dichotomy, and thus there is a comparatively reduced importance on ensuring connectivity between protected areas – as productive land is often suitably biodiverse to enable non-human animals to transit between them and link up with populations elsewhere. Semi-natural areas, and restored strips around the edges of farms ensure landscape connectivity.

IPLC are seen as the best guardians of protected areas in recognition of the fact that they have often been successfully ecologically stewarding them and acting as their guardians already (Tran et al, 2019), but also out of a new recognition for their sovereign right to self-determination. Protected areas are focused on preserving culturally significant landscapes and emblematic species. Communities have a strong degree of autonomy over where PAs are sited and determine sites that best promote local welfare, while ensuring that no community member takes on an undue share of the burdens. There is considerable freedom within communities for how the global 30% target will be shared between community members, and this is a decided through a long process of community deliberation to ensure that the process is understood to be fair, and equitable solutions are found for those who are

inconvenienced. IPLC are given significant new authority to manage their territories and are able to ensure against exclusionary protected area policies. IPLCs are respected as the best managers of their PAs, and their connection, knowledge, and experience is valued. Restoration of IPLC political control over their territories is understood as a cornerstone of biodiversity positive change. The commitment in the Global North to greatly reduce their consumption footprint gives communities in tropic regions more "breathing space" to allocate land to protected areas without compromising food security or their development strategies.

While the people and societies in this pathway are committed to a "think globally – act locally" mentality, and so there is a voluntary solidaristic commitment to ensuring that communities who must give up productive land and associated opportunities to non/limited use protected areas are compensated. The "fair" standard of compensation is based on a moralized egalitarian baseline (Armstrong, 2024). Compensation for the loss of territory to protected areas calculated against the opportunity cost lost compared to what the occupant would need to be earning in order to live an equal and sustainable standard of living. Communities make communal decisions to ensure that they meet 30% targets without unfairly inconveniencing any particular members. Recognition of the historical responsibility in contributing to biodiversity loss through past overconsumption leads to countries in the Global North compensating nations in the Global South for the costs of taking on protected areas needed for halting global biodiversity loss and essential global ecosystem services.

While this pathway is committed to a balanced relational-intrinsic valuation of nature, some biodiversity offsetting is permitted. However, there are strict rules governing how schemes can be organized. Offsetting regimes accord with best practice "like-for-like" and "local-for-local" principles, only permitting offsets between ecosystems of the same type, and offering a premium for finding "replacements" in nearby locations so that communities do not loose access to the cultural and recreational benefits of having green-space/nature in proximity to them. This ensures that offsetting can play a role in lowering the costs of development while not severing the cultural/relational link communities have with

their natural surrounds.

In this future the EU is patchworked with OECMs and moderately protected areas in culturally significant sites, and to support provision of pollination and water management services. PAs may have some economic uses within them and focus on developing rich biocultural landscapes with high amenity and aesthetic value. The EU supports PAs abroad by accepting historical responsibility for biodiversity loss, cutting consumption and onshoring production.

§6.3.4 Sustainable Consumption:

In this pathway, individuals voluntarily adopt more sustainable lower consumption lifestyles. This voluntary shift is motivated by the fact communities understand themselves as having egalitarian and limitarian ethical obligations to their fellow people across the world and recognize that only by reducing consumption in high consumption region today can space be found to raise consumption and progress toward equality elsewhere. Indeed, communities recognise that inequality within societies is a driver of biodiversity loss (Cushing et al, 2015; Mikkelson, 2007; Holland et al, 2009; Hamann et al, 2018; Pandit & Laband, 2009) as see reducing inter-society inequality as a sustainability measure in and of itself.

However, beyond just the obligations which they see themselves as having toward other communities and people, in this pathway people intrinsically value the connections they have with the natural world and its nonhuman inhabitants, and lowering consumption is needed to make space to have flourishing and meaningful connections with nature built on a basis of mutual respect. In the global north, the limitarian ethical principle prevents consumption rising over a certain amount, and this allows for a greater degree of consumption to be budgeted for development in the global south. This is seen as following from a recognition of the egalitarian principles and in respect of the historical responsibilities borne by those in the global north who have historically used a greater than legitimate share of the Earth's resources. Communities and their governing bodies make strong voluntary commitments to reducing consumption. In particular, communities in the global

north recognize their historic over consumption of good and make especial efforts to transition to a planetary health diet and cutting luxury consumption.

From a mitigation hierarchy perspective this pathway is focused on the prevention of biodiversity loss causing products, by lowering overall consumption globally. There is a switch to less damaging consumer products, produced through organic and labour-intensive methods; but this switch is facilitated by demand falling overall. This future also sees the highest reduction in household/consumer waste. The shift in consumer values, as well as the broad shift in the way food is consumed and resources are used, ensures that everything produced is produced with durability in mind. Prices of most goods are comparatively higher in this pathway, and consumers necessarily do not use more than they need to live fulfilling and meaningful lives. As dietary consumption habits shift towards traditional dietary practices and recipes food is used more frugally and less goes to waste. People increasingly live lives as parts of their local communities, frequently coming together to cook and eat communally which lowers the waste associated with cooking alone. Food waste is composted and feeds back into an increasing circular local agricultural economy.

Consumption is reduced predominately via life-style changes towards sustainable practices. Especially in the global north there is a huge scale-back in resource consumption as society shifts towards localized economies that distribute resources according to need. As consumption falls in the global north, the prices of goods on the global market falls and countries and regions in the global south are able to sustainably raise consumption and move towards global equality. There is also active north-south redistribution of goods in order to ensure that the globally limitarian pattern of justice is progressed towards. While this is a more equal world than both our world, and the other pathways, there is still inequality between world regions and polities, but the world is progressing towards equality within regions, while ensuring all regions are within a min-max consumption window. The shift towards a sufficientarian global needs-based economy necessitates a new way of thinking about the referent points for consumption. All regions agree that a minimum standard of consumption globally should be set based on a referent point of what is needed to live a healthy and fulfilling life, and all regions agree to cooperate to ensure that

this is attained by everyone, everywhere.

§6.3.5 Bioenergy and Carbon Sequestration:

The focus on low impact extensive agricultural and forestry protection leaves little room for BECCS. As consumption is low in this pathway this largely negates the need for substantial quantities of BECCS. Instead, the carbon sequestration focus is nature-based, and focused on raising the capacity of terrestrial carbon sinks, both in natural lands through restoration, but also in managed land through a shift in agricultural and forestry techniques. Carbon removals were achieved elsewhere particularly on farms themselves through a shift to soil building through organic and low-till agricultural techniques, including labour intensive peasant-led farming (Woodhouse, 2021). Afforestation and reforestation also play a major role in global carbon management, including through forest restoration measures that convert fast growing highly managed forests into forests with greater understory. This pathways reduction in overall consumption (per capita) and a higher on-farm capture of carbon means that the terrestrial carbon sink expands to the point where novel carbon capture mechanisms are not in high demand.

Likewise, the decentralization of authority and local onshoring of resource production leads to a preference for distributed energy systems, e.g., solar and wind, rather than centralized energy production facilities such as nuclear. Indeed, this decentralization of the energy system provides a barrier to BECCS implementation as industrial scale BECCS requires centralized and energy intensive pyrolysis plants. Some regions with excess waste biomass may incorporate modular bioenergy plants using waste wood or agricultural straw to form locally circular carbon economies. Wood is very seldom used as a fuel source, as it is seen as too valuable for this purpose and the land-footprint costs are seen as too high. Transfers of technology including solar panels and wind energy supports a commitment to electrification globally, reducing the need to use wood as a fuel source globally.

§6.4 Feasibility

§6.4.1 Actors and Motivations

In this pathway the key drivers of change would be the local communities themselves. Local communities might exert consumer leverage to push for a shift to local scale and culturally valuable production. Small-scale producers might find ways to resist globalization, motivated by a desire to continue living and working in their traditional ways. In general people are motivated by their values and justice preferences, particularly the importance of their culture, community, sense of place and respect for their local environment, and a preference for devolved political authority that puts them at the centre of political decision-making and allows them to exert control over their communities and surroundings.

Central to recognizing historical responsibility for biodiversity in the global north is an acceptance of the differentiated responsibilities that this gives these states for bearing the burdens of protecting and restoring biodiversity. In part this is understood as a responsibility to financially contribute to the adaptation of states in the global south – providing them with the finance and fixed capital necessary to transition to biodiversity friendly means while progressing towards greater overall equality by allowing for development. Currently, the wealth and power of states in the global north allows them to export polluting and space consuming industries (e.g. mining) abroad, allowing them to protect important cultural and biodiverse landscape, and the expense of those abroad. Part of taking responsibility, and in the spirit of global egalitarianism and solidarity, is understanding that there might be local reductions in biodiversity in the global north which are necessary for allowing greater space for biodiversity abroad.

§6.4.2 Expected Impacts.

This pathway scenario involves a fundamental shift in our food systems, away from globalized, industrial agriculture towards more localized, sufficiency-based, and extensive farming practices, coupled with reduced international trade. Increased local stewardship prioritizes diverse, regionally adapted crops and livestock breeds,

which are more resilient to local conditions and contribute to on-farm biodiversity in contrast with industrial agriculture's reliance on a few high-yielding varieties. This could lead to reduced reliance on synthetic fertilizers and pesticides benefitting pollinators, soil organisms, and other wildlife (Gomiero et al., 2011; Smith et al., 2019). In addition, this leads to more varied landscapes, with a mosaic of small fields, hedgerows, and natural habitats, providing diverse niches for wildlife (Staley et al., 2023). And the issue of lower land use intensity increasing pressure on land use is largely mitigated by the reduction in demand to sufficiency levels. Therefore, the impacts are derived from three areas: 1. Moving to Extensive Farming, 2. Reduction in demand for agricultural goods to sufficiency levels, and 3. Reduction in trade via increased trade barriers from higher standards of environmental regulation.

1. Moving to Extensive Farming

Extensive farming is characterized by lower input use, larger field margins, and less intensive practices therefore providing more space for natural habitats within agricultural landscapes. This benefits a wide range of species, including pollinators, birds, and small mammals. The lower input use would enhance soil biodiversity, structure, and fertility, reducing the need for synthetic inputs. This would in turn lead to reduced pollution. Less reliance on synthetic fertilizers and pesticides directly translates to less chemical runoff and fewer greenhouse gas emissions, benefiting aquatic and terrestrial ecosystems. Healthy and biodiverse agricultural landscapes can then provide essential ecosystem services like pollination, pest control, and water filtration.

2. Reduction in demand for agricultural goods to sufficiency levels

The most direct and substantial benefit for biodiversity, if demand for agricultural goods decreases to only what is needed for sufficiency (i.e., less food waste, reduced overconsumption, and potentially a shift towards less resource-intensive diets), would be large areas of land currently under agriculture could be rewilded or restored to natural habitats. This allows greater opportunity for ecological restoration enhancing ecosystem services and biodiversity (Otero et al., 2024). There

would also be less pressure on water and other natural resources from agricultural production. Also, a smaller agricultural footprint, especially from reduced livestock production and less land conversion, would significantly lower greenhouse gas emissions, mitigating climate change's impact on biodiversity (Alexander et al., 2017).

3. Reduction in trade via increased trade barriers from higher standards of environmental regulation

Currently, global trade often shifts the environmental burden of food production to biodiverse regions (e.g., deforestation for soy or palm oil). Reduced trade, especially from environmentally sensitive areas, would alleviate this pressure. With fewer imports and higher intrinsic motivation for sustainable agriculture, there's a greater incentive to produce food domestically using sustainable methods, as environmental degradation within national borders becomes a more immediate and visible concern (Bopp et al., 2019). Reduced demand for internationally sourced agricultural products would decrease the conversion of natural habitats for export-oriented farming. And less reliance on imported goods encourages consumption of locally available and seasonally appropriate foods, often leading to more diverse dietary patterns that support local agricultural biodiversity (Vargas et al., 2021).

§6.4.3 Government:

In this pathway power is devolved away from global institutions and recentred into local communities. This is based both upon a pragmatic belief that local governance organizations will be better able to make ecological decisions which are sensitive to the local ‘conditions on the ground’, and better reflect both ecological and cultural specificities; but also on the moral foundations of this pathway’s egalitarian focus. The decentralization of authority allows for a flattening of governance hierarchies, and for a government which can more sensitively and directly deal with the community’s needs and foster a culturally infused ethical relationship with nature. (Bookchin, 2007; Plumwood, 1993). Decisions are made (directly) democratically through citizens assemblies, and measures are in place to limit the formation of

hierarchies and dominance – such as by ensuring polycentric decision making which can resist the ossification of power and leadership roles into a single actor's hands (Perlaviciute, 2024; Schmid et al, 2024).

Governance in this pathway is substantially devolved away from global and national levels, down to smaller self-determining jurisdictions. The result is that there is a wide diversity of governing organizations and different communities find plural ways of legislating and governing for themselves, in ways which accord with their vision of justice. Regions (including rural and urban regions) cooperate with each other bilaterally to share and exchange the goods which they produce, and coordinate production to meet each other's needs. Government supports the transition to a biodiversity positive future by guiding production and cultural development in nature positive directions. As power localizes, each governing authority exerts control over a smaller area – which allows the government to make very targeted and regionally specific interventions to support biodiversity positive action in a way amenable to the needs of its local community. However, there is comparably less coercive authority to ensure compliance between regions – and relations between polities has to be conducted on the basis of good will and solidarity. Governments are values led and try to make bilateral agreements with polities who they feel share their values.

The shift away from globalization and towards a post-growth models gives the governments of new regional polities a fractious relationship with markets. Markets, especially markets directly linking producers to consumers, may continue to exist on a national level, but the shift to an egalitarian vision of justice, and the need to substantially reduce consumption over all leads to a serious effort to temper the inequality which markets and commodity production leads to. Instead, goods might be exchanged on a market according to their use-values, and governing authorities might intervene to ensure that goods are shared equitably or on the basis of their economic contributions. These methods are seen as necessary in order to ensure that everyone's needs are met while continuing to transition to an economy which fits within planetary boundaries.

Smaller scale polities open up possibilities for new types of governance to emerge,

including highly participatory directly democratic forms. Important decisions may be made by consensus, and citizens have powers to recall their officials if they fail to meet their promises to facilitate equality or meet pre-agreed targets for the transition. Likewise, the devolution of authority means that previously subaltern groups are able to have a greater say in the governance of their communities. Additionally, the governments' focus on supporting/fostering a cultural relationship with the natural world entails supporting new and experimental nature positive ways of living. IPLC benefit particularly, receiving the option of forming independent sovereign polities. However, the active role that governments now play in acting as cultural custodians means a greater deal of scope for governments intervening in private lives and ensuring cultural conformity within regions, in a way liberal government would have guarded against.

In this pathway, the EU sees substantial regional devolution, and supports states in restructuring political authority, while providing regions with a forum for political negotiation and a means to coordinate production between regions and manage trans boundary problems. The EU allows regions a greater deal of autonomy to make environmental planning decisions. Globally the EU supports regions in making global links and supporting trade deals, as well as facilitating reparations payments to support conservation abroad and account for historical responsibility. The EU is a loose confederation of small regional polities and plays an advisory and role with little coercive authority to intervene in its member nations affairs.

§6.4.4 Enablers:

The chief benefit to this pathway is that it avoids the coercive authority that can be found in IMI and GSO. Instead, it relies on moving political authority to local levels which can facilitate direct involvement in political processes. This may help in ensuring that decision making is perceived to be legitimate which may help in managing resistance. It may also be a good in and of itself if we think that justice requires a greater deal of autonomy and control over the political decisions which we are governed by. Likewise, the extensive agriculture/land-sparing approach entails that less land is devoted to protected areas, and in this way both resentment

to environmental objectives, and displacements of people may be avoided.

As a communitarian view, this pathway emphasizes a common-good rather than liberal-individualistic approach to politics. Common-good theories imply the existence of some sort of coercive mechanism which can bring detractors into line, and to this extent the diverge from liberal theories of justice which emphasize the protection of the individual's rights and freedoms from coercion.

§6.4.5 Barriers:

Actors adhering to communitarian viewpoint (and recognition of historical responsibility) represent a minority today, and opposition from powerful actors today to the required overhaul of economic structures could be large. The fact that this pathway is highly driven by a shift in global values presents a major barrier to implementation. This factor is compounded by the fact that the actors who either already exhibit these values, or who might otherwise benefit the most from this pathway, currently lack political, economic, and cultural power; and thus, will face an uphill battle to try and leverage influence for a shift in global power dynamics to facilitate this pathway. Likewise, while Ostrom and others have pointed to the ability of self-organised communities to manage resources sustainably (Ostrom, 2009; Federici, 2018) it is typically argued that the management of common goods requires coercive authorities which can bring bad actors into line and resolve the tragedy of the commons" (Hardin, 1968; Hobbes, 1970). We might expect that as this pathway sees a shift to devolving political authority, and a shift to non-coercive face-to-face democratic societies communities may face challenges in finding solutions to the collective action problems which arise when managing environmental problems. Societies built around a normative common-good conception of politics require mechanisms to create adherence to their particular vision of the "common good". However as this pathway focuses on reducing centralised authority it is unclear what the coercive mechanisms might exist to compel adherence from those who do not share their local communities' vision of the common-good. This lack of a clear

coercive mechanism may mean that the pathway is impotent at bringing about the transformative changes that are needed to meet its environmental and social aims.

The focus on localizing production may also be difficult to achieve while also attempting to move towards an egalitarian global distribution. Natural variations in the distributions of global resources mean that some regions are inherently more productive, or simply co-located with valuable resources. Some settlements and societies' existence is built upon extracting resources and exchanging them on global trade networks (e.g., the gulf states or small islands currently reliant on tourism, as well as urban areas generally) – so how a shortening of supply chains and refocusing on local agricultural production to meet needs would impact these communities and remain consistent with progressing towards equality is unclear. The opposite dynamic is also true. Some regions of the USA, the Netherlands, and Brazil (for instance) are also major exporters of agricultural products, and while these sectors often make up comparatively small shares of overall economic output (and often employ comparatively small numbers of people).

Likewise, the communitarian character of this pathway, and the focus on attaining cultural goods might entail that some communities adopt illiberal social/cultural norms. This pathway emphasizes the appreciation of plural and culturally informed ways of living with/as nature – but the trade-off here may be over the ability to critique the culture of others from a liberal universalism/equal rights perspective. While global pathways like GSO might have mechanisms to promote equality of sub-altern groups – for instance promoting woman's rights – it is not obvious how a pathway built on a reducing authority globally might continue to progress on these social aims, or what methods it might have to confront intransigence.

B - DATABASE ON DOWNSCALED BIODIVERSITY TARGETS

§1 Introduction

In light of the global biodiversity crisis, ambitious goals and targets to bend the curve of biodiversity loss and "live in harmony with nature" have been stated in the CBD Kunming-Montreal Global Biodiversity Framework (KMGBF, CBD 2022a). The KMGBF formulates goals and targets to be achieved on a global scale but will be implemented on a national scale by its member states, which must update their National Biodiversity Strategies and Action Plans (NBSAPs) and set national targets to collectively contribute to achieving the global ambitions of the KMGBF. Different perceptions of justice, particularly distributional justice, and different value perspectives for nature may influence what is seen as an appropriate distribution of efforts towards these global biodiversity targets.

Distributional justice is a form of justice concerned with the distribution of benefits and burdens (Hanger-Kopp et al. 2024). Diverse perspectives exist and are being debated, on what a "fair" distribution constitutes, e.g.: Grandfathering is a principle of sovereignty, where current resource use reflects a "status quo" right. This principle is often invoked by Global North countries but has also been criticised as contradicting principles that aim to protect the vulnerable and promote sustainable development. Egalitarian patterns of distributional justice aim at minimising differences between entities, e.g., by an equal per capita distribution of benefits or burdens. Capacity is a principle under which those who can afford more should carry a larger share of the burden, often implemented as ability to pay. Utilitarian patterns of distributional justice aim at maximising total well-fare, e.g., by distributing benefits or burdens in a cost-effective or efficient fashion (Dooley et al. 2021, Hanger-Kopp et al. 2024, Lucas et al. 2020). The AJUST framework (Hanger-Kopp et al. 2024), introduced in section 2.1 of this document, can support systematising different preferences for distributional justice in the context of target downscaling.

A useful framework to understand and conceptualise different value perspectives

for nature is the Natures Futures Framework (NFF), which distinguishes three main forms of values for nature as well as diverse combinations of them: nature for nature, referring to the intrinsic value of nature, i.e., valuing nature for its own sake; nature for society, referring to the instrumental value of nature, i.e., valuing nature for the benefits it can bring to people; and nature as culture, referring to the relational value of nature, i.e., valuing nature for the reciprocal, cultural and spiritual relationships one can have with it (Pereira et al. 2020).

As both justice as well as value perspectives for nature are critical aspects of successful transformative change for biodiversity (IPBES 2022, 2024), it is essential to explore the role of justice and values in the context of how national contributions towards the global KMGBF goals and targets can be distributed. One approach to this is downscaling global targets to the national scale according to different principles of distributional justice. This implies translating targets formulated at the global level to quantitative contributions of individual countries. Such an approach has previously been applied to greenhouse gas emission budgets and planetary boundaries (e.g., Bai et al. 2024, Lucas et al. 2020) and could be enriched with value perspectives for nature.

§2 Scope and aim of the quantitative work covered in the deliverable D1.3 database

As part of the RAINFOREST project, we implement such downscaling of global KMGBF targets under alternative distributional scenarios informed by different principles of distributional justice and value perspectives for nature. The purpose of this exercise is to explore possible quantitative implications of different perceptions of distributional justice and value perspectives for nature in the context of pathways for transformative change for biodiversity. Outcomes of these analyses are not intended to be blueprints for quantitative target setting at the national or other scales, but rather to inspire and support discussions on burden sharing related to collectively achieving global biodiversity targets and the implications of justice and value perspectives in this context. They can also be used to enrich the pathways developed within RAINFOREST and to highlight quantitative implications and potential trade-offs of different justice principles tied to the narratives of the individual pathways. Stakeholder interactions throughout the RAINFOREST project,

in which the ideas and some results of the downscaling were discussed, revealed that the interest in such an exercise is high and that results from it can indeed inspire lively debates about burden sharing in the context of biodiversity targets.

To exemplify this, we selected three KMGBF targets which capture different aspects highly relevant to food and biomass production and consumption (CBD 2022a): KMGBF target 3 aims to ensure and enable that by 2030 at least 30% of land and sea are effectively conserved and managed and is relevant to food and biomass production, as area-based conservation can limit the land available for other uses; KMGBF target 7 aims, among others, to reduce excess nutrients lost to the environment by at least half by 2030 and is relevant to food and biomass, particularly agricultural production which is an important source for nutrient loss; and KMGBF target 16 aims to reduce the global footprint of consumption in an equitable manner by 2030, which also affects the footprint of the consumption of food and biomass products. Since each of these targets affects different aspects of food and biomass production and consumption, and has its own context, we decided to tailor the downscaling scenarios specifically to each target, rather than adopting a one-size-fits-all approach. The details of how scenarios have been implemented is described below.

The outputs of this exercise constitute a database which serves as deliverable D1.3 of RAINFOREST. The text of this section of deliverable D1.2 serves to describe the underlying rationale, methods, data, to highlight some results, and to outline potential next steps in this strand of research. Technical metadata description on the format and structure of the database is part of D1.3.

In the following section we describe the work on each of the three targets separately, followed by a brief section on how looking at results for different principles across targets can highlight potential synergies and trade-offs between targets and strategies to reach them.

§3 Target 3: Conserve 30% of Land, Waters and Seas

Target 3 is possibly the most widely known target of the KMGBF aiming *"[…] that by 2030 at least 30 per cent of terrestrial, inland water, and of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem*

functions and services, are effectively conserved and managed […]" (CBD 2022a). Here, we focus on conservation on land, which can restrict the area available for food and biomass production, while particularly the expansion of agricultural areas already threatens existing protected areas (Arneth et al. 2023, Vijay et al. 2021, Wang et al. 2023). Such trade-offs between food and biomass production and area-based conservation may also be influenced by how strict an area is protected determining to what extent human activities, such as extensive agriculture, might be allowed in these areas, although that also depends on how effectively the respective management category is implemented on the ground. Locating areas for protection can raise questions of distributional justice. Taking land out of other uses to put it under protection can represent a financial burden and reduce the availability of land for purposes such as food production. At the same time, protecting local biodiversity and nature's contribution to people (NCP) may be considered an advantage for a country. Therefore, depending on one's perception of distributional justice and the importance one assigns to these issues, one may want to adopt different principles for distributing the global share of areas under protection, along with the associated benefits and burdens.

§3.1 Indicator and data

We focus on conservation on land measured as absolute and relative coverage of protected areas (PAs) and other effective area-based conservation measures (OECMs), the headline indicator for target 3 agreed upon by the CBD in the monitoring framework for the KMGBF (UNEP-WCMC, 2025).

We computed the current coverage of PAs and OECMs as well as different IUCN management categories of each country based on data from the UNEP-WCMC and IUCN, Protected Planet: The World Database on Protected Areas (WDPA) (downloaded in June 2024, UNEP-WCMC and IUCN 2024). This dataset provides shapefiles (polygons and point data) of PAs. We calculated the area under protection and fraction of area under protection per country based on the PA shapefiles and GADM data version 4.1, administrative level NUTS0 (GADM, 2025). For PAs, for which only point data was provided, areas were not considered in this calculation. We considered the IUCN management categories Ia, Ib and II as strict protection. These data were also the input to quantify the grandfathering scenario (details below).

To approximate a scenario of environmental capacity, interpreted as maximisation of biodiversity coverage (detailed explanations below), we utilised data provided by Jung et al. (2021a, b), who identify priority areas that would minimise the number of threatened species if put under effective conservation. We utilised their data provided at 10 km spatial resolution, focusing on biodiversity only and included two versions, one that considers existing PAs as of 2019 and one that does not.

To approximate a scenario of efficiency, here interpreted as maximisation for carbon storage at minimised cost (detailed explanations below) we utilised data on vulnerable and irrecoverable carbon in terrestrial ecosystems provided by Noon et al. (2021, 2022). For easier handling, we aggregated this data by a factor of 6 to a 1.8 km resolution taking the mean value across grid cells prior to further analyses. To estimate cost, we used data provided by Naidoo & Iwamura (2007) approximating agricultural opportunity cost by integrating spatial information on crop productivity, livestock density, and prices to produce a global map of the gross economic rents from agricultural lands.

§3.2 Implementing different ways to achieve 30% conservation on land

We first derived a quantitative global budget from target 3 using the selected indicator. This budget was then distributed between countries according to different scenarios capturing different perceptions of distributional justice and values for nature. For KMGBF target 3, the global budget is 30% of land area under protection. To also explore some scenarios of how strict protection could be distributed, we went with the target of the EU to put 10% of land under strict protection (European Commission 2020) and assumed the same target at the global level although this was not further specified in the KMGBF target 3. We explored four scenarios to distribute the global targeted 30% of conservation on land between countries: efficiency, environmental capacity, equal share, and grandfathering.

Efficiency: This scenario combines the idea of an “efficient”, or “cost effective” global distribution of conservation on land, with a “nature for society” perspective, assuming a distribution of PAs and OECMs that maximises the protection of NCP at minimal cost. We selected the example of carbon storage, an important regulating

NCP, to distinguish the efficiency scenario from the environmental capacity scenario (see below). However, other NCP, as well as measures of biodiversity itself as proxy for NCP could also be used to inform an efficiency scenario for distributing PAs and OECMs. We approximate the efficiency scenario, by maximising the coverage of irrecoverable and vulnerable carbon at minimised agricultural opportunity cost, knowing well that this is a simplified approximation of the cost of area-based conservation. We currently implement this without accounting for existing PAs and OECMs but plan to implement the latter in future versions of the database. The efficiency scenario aligns with the International Market Innovation pathway.

Environmental capacity: In this scenario, we combine a "capacity" perspective on distributional justice, with a "nature for nature" value perspective, assuming a distribution of PAs and OECMs that maximises the protection of biodiversity so that regions, that have a higher capacity to protect biodiversity have larger shares of areas under protection. To approximate this scenario, we used data provided by a published prioritisation study (see above). Two versions are considered, one that accounts for current PAs (as of 2019) and one that does not. Following discussions with stakeholders relevant for area-based conservation, we implemented the environmental capacity scenario both to distribute the global 30% of protection and the hypothetical global target of 10% area under strict protection. The environmental capacity scenario aligns with the Global Sustainability Orchestration pathway.

Equal share: This scenario assumes that every country protects 30% of their land, which is one interpretation of an egalitarian distribution of conservation of land. The equal share scenario aligns with the Local Commons Stewardship pathway. Following discussions with stakeholders relevant for area-based conservation, we implemented the equal share scenario both to distribute the global 30% of protection and the hypothetical global target of 10% area under strict protection.

Grandfathering: This scenario assumes that every country contributes the same share to the global total area under protection as currently.

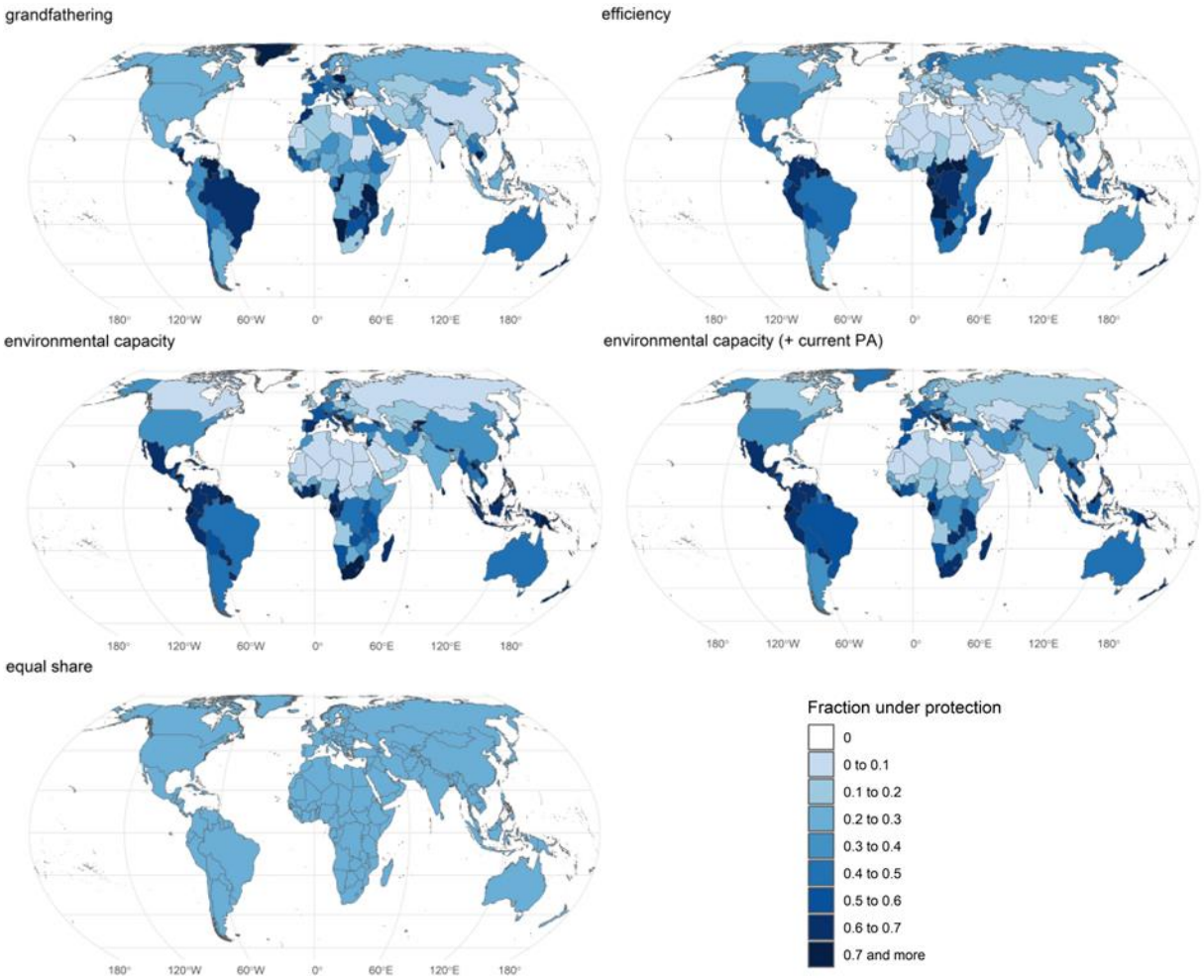


Figure 5. Map of the fraction under protection in each country according to the grandfathering, efficiency, environmental capacity (without and with considering current PAs), and equal share scenarios to distribute the global budget of 30% conservation on land.

Implementing the scenarios described above revealed that both, an efficiency and an environmental capacity scenario (when current PAs are not considered) would place relatively large fractions of land under protection and under strict protection in tropical and subtropical regions, e.g., Brazil or Indonesia. They differ, however, in that the efficiency scenario would also place higher fractions to the North of Europe, Russia and the USA, while under the environmental capacity scenario, the West and South of Europe have larger shares under protection. Stakeholder discussions concluded that distributing strict protection according to environmental capacity, i.e., where biodiversity benefits are highest, should be preferred over a generalised equal share approach, although this should account for, and allow, low impact use by indigenous peoples and local communities. Similarly, there was some consensus that biodiversity, including ecosystem representativeness (and NCP), should guide the global distribution of the targeted 30% of area under protection,

while the needs of people living in these areas, historical responsibilities as well the legacy of colonialism should be considered, and international financial transfers might be needed.

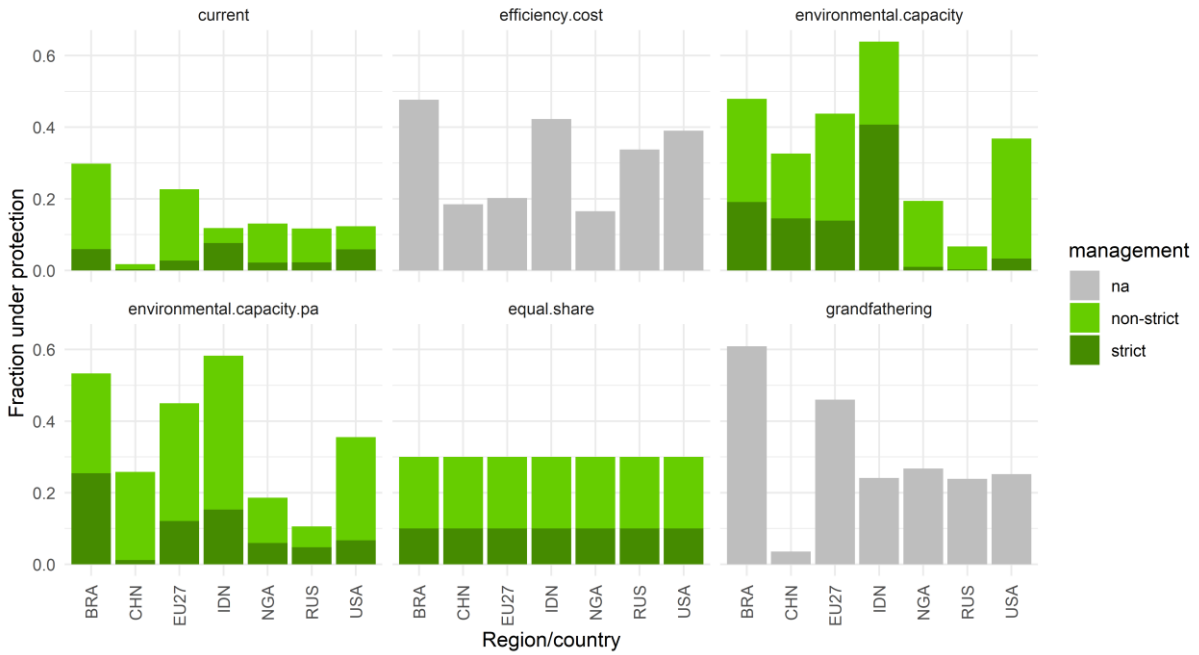


Figure 6. Fraction of area under protection and under strict protection currently (baseline: year 2024, data aggregated from WDPA, see above) and under the efficiency, environmental capacity (with and without considering existing PAs as of 2019), equal share and grandfathering scenarios for seven example countries/ regions. Note that the efficiency and grandfathering scenarios have not been implemented to distribute area under strict protection, therefore the management category is "na" for these scenarios. Strict protection refers to areas under protection that are managed according to the IUCN management categories Ia (strict nature reserve), Ib (wilderness area), or II (national park). Non-strict refers to all other areas that do not fall under these management categories.

§4 Target 7: Reduce Pollution to Levels That Are Not Harmful to Biodiversity

Target 7 of the KMGBF includes the aim to by 2030, *"[…] reducing excess nutrients lost to the environment by at least half including through more efficient nutrient cycling and use; […]"* (CBD 2022a). Target 7 also captures other crucial sources for pollution including plastic pollution, and pollution from pesticides and hazardous chemicals. Here, however, we focus on the aspect of reducing excess nutrients lost to the environment, as biomass production, in particular agricultural production, is

a major source for nutrient pollution. We exemplify this with cropland nitrogen. Reducing excess cropland nitrogen lost to the environment can be achieved by reducing nitrogen inputs or by improving nitrogen use efficiencies, which raises questions of distributional justice as these measures can come with financial burdens and may also affect the amount of food and other biomass products that can be produced.

§4.1 Indicator and data

The headline indicator for nutrient pollution in the CBD-KMGBF monitoring framework is the index of coastal eutrophication potential (UNEP-WCMC, 2025). However, Möhring et al. (2023) argue that indicators which capture sources of nutrient loss, such as nitrogen surplus, are more effective in informing and implementing policy to reduce nutrient pollution. We focus on the indicator of nitrogen surplus over cropland because croplands are a main source of global nitrogen pollution (Gu et al., 2023). Nutrient loss to the environment also results from other sources, such as wastewater, and emissions from industry and transport (Schulte-Uebbing et al. 2022a. CBD, 2025), but apart from accounting for nitrogen input to cropland from atmospheric deposition, this will not be covered in our example. We take a production perspective for downscaling target 7, i.e., we focus on nutrient loss related to the crop production of a country.

The downscaling of the nutrient loss target was mainly based on data from EARTHSTAT (West et al., 2014) providing nitrogen balances over global croplands for 140 different crops at a spatial resolution of five arcminutes for the year 2000 (average of crop census and statistics between 1997-2003). We aggregated these data to the level of NUTS0 administrative units using shapefiles from GADM 4.1 (GADM, 2025). For our analyses, we further aggregated the data to the level of the following crop groups: cereals, fruits, oil crops, sugar crops, vegetables, pulses, roots and tubers, and other (Table 8). In each crop group, we only included countries' production that contributes to the top 99.5% production of the crop group. The grandfathering, efficiency, equal per hectare and sufficiency scenarios (details below) were mainly based on information derived from these data.

The environmental capacity scenario (details below) was based on data by Schulte-Uebbing et al. (2022a, b) providing regional boundaries for nitrogen surplus

over agricultural land, considering thresholds for aquatic and terrestrial eutrophication as well as drinking water quality at a spatial resolution of 0.5 x 0.5° for the year 2010. We utilised their data on arable land considering all three thresholds and aggregated these data to the level of countries (NUTS0 administrative units) using shapefiles from GADM 4.1.

Information on the share of feed for each crop in each producer country was updated from Vanham et al. (2023).

For the equal per capita and the sufficiency scenarios (details below), we used population data from the UN World Population Prospects 2024 revision (U.N., 2024) focusing on the Total Population, as of 1 July in the year 2000 (to match the EARTHSAT data).

§4.2 Implementing different ways to achieve a reduction of nutrient loss by half

We first derived a quantitative global budget from target 7 using the selected indicator. This budget was then distributed between countries according to different scenarios capturing different perceptions of distributional justice and values for nature. For the nutrient loss aspect of KMGBF target 7, the global budget is 50% of the current global sum of nitrogen surplus (here over cropland). We explored six scenarios to distribute the global budget for nutrient loss between countries: efficiency, environmental capacity, equal per capita, equal per hectare, sufficiency, grandfathering.

Efficiency: This scenario adopts an "efficiency" perspective on the distribution of the global nutrient loss budget, interpreted as reducing nutrient loss most, where it is used least efficiently. We approximate this by distributing the global nitrogen surplus budget linearly with the nitrogen use efficiency (NUE) of a country. Soil mining countries (i.e., those with a NUE >1) were assumed to achieve the global average NUE of a crop group. The efficiency scenario aligns with the International Market Innovation pathway.

Environmental capacity: This scenario combines a "capacity" perspective on distributional justice with a "nature for nature" value perspective, following regional environmental boundaries to distribute the global nitrogen surplus budget. To

approximate this scenario, we aggregate data provided by a published study on regional boundaries for nitrogen surplus (see above) to the country scale. The environmental capacity scenario aligns with the Global Sustainability Orchestration pathway.

Equal per capita: This scenario distributes the global nitrogen surplus budget equally per capita, one interpretation of an egalitarian distribution of the global nutrient loss budget.

Equal per hectare: This scenario distributes the global nitrogen surplus budget equally per hectare cropland assuming similar amounts of cropland as in the baseline data, another interpretation of an egalitarian distribution of the global nutrient loss budget.

Sufficiency: The "sufficiency" scenario follows the idea that each country should be allowed a nitrogen surplus budget that enables it to produce enough crops to feed its inhabitants (but not more than that). We here implement a simplified version of this by distributing the current nitrogen harvested equally per capita, and improving NUE in each country to a maximum of 0.7 until the global 50% reduction target for nitrogen surplus is reached.

Grandfathering: This scenario assumes that each country reduces its current nitrogen surplus by 50%, maintaining the existing relative distribution of nitrogen surplus across countries within the global budget.

All scenarios, except the environmental capacity scenario, were implemented at the crop group level, i.e., a 50% reduction of the current nitrogen surplus was achieved within each crop group.

In addition to the scenarios implemented to downscale the global nutrient loss target to the country level, we compare two approaches for allocating nitrogen surplus between crop production for animal feed and for food and other uses. The first is a scenario, in which each country's nitrogen surplus budget is divided between feed and food crops in proportions that reflect current distributions. The second scenario prioritises food production, allocating a maximum of 15% of the nitrogen surplus to feed crops.

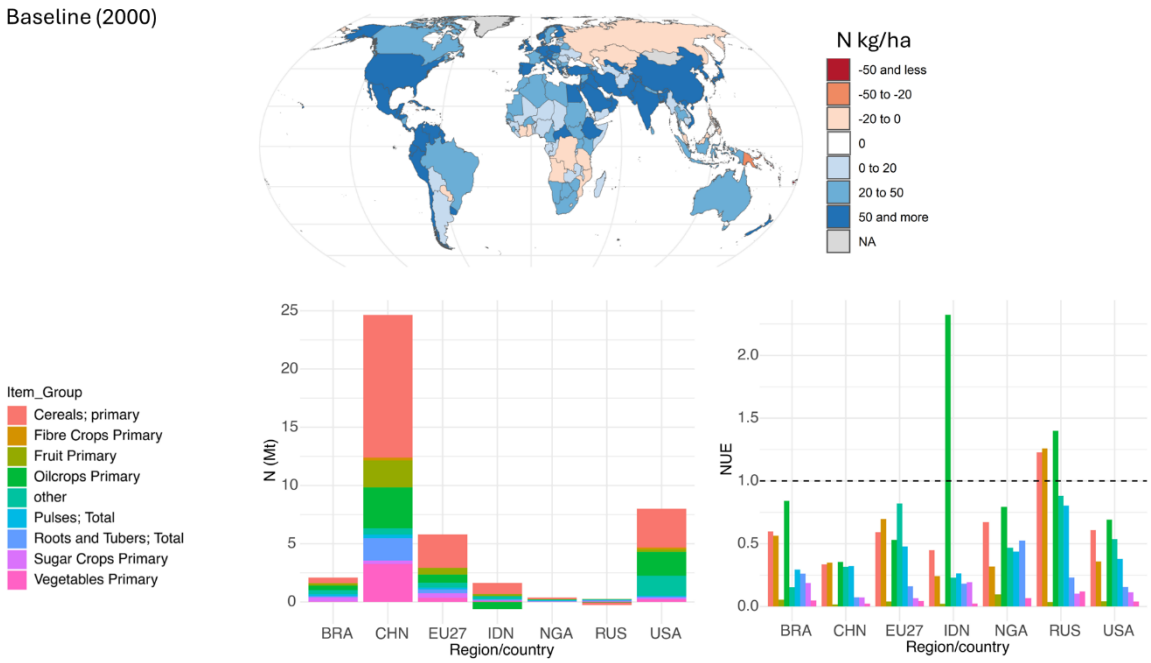


Figure 7. The baseline, referring to the year 2000 (EARTHSTAT data): top: map of the current nitrogen surplus (kg/ha/yr), bottom left: current nitrogen surplus (Mt/yr) and bottom right: NUE per crop group for seven example regions/ countries. NUE values above the stippled black line indicate soil mining, i.e., less nitrogen is applied to croplands than is removed through crop harvest.

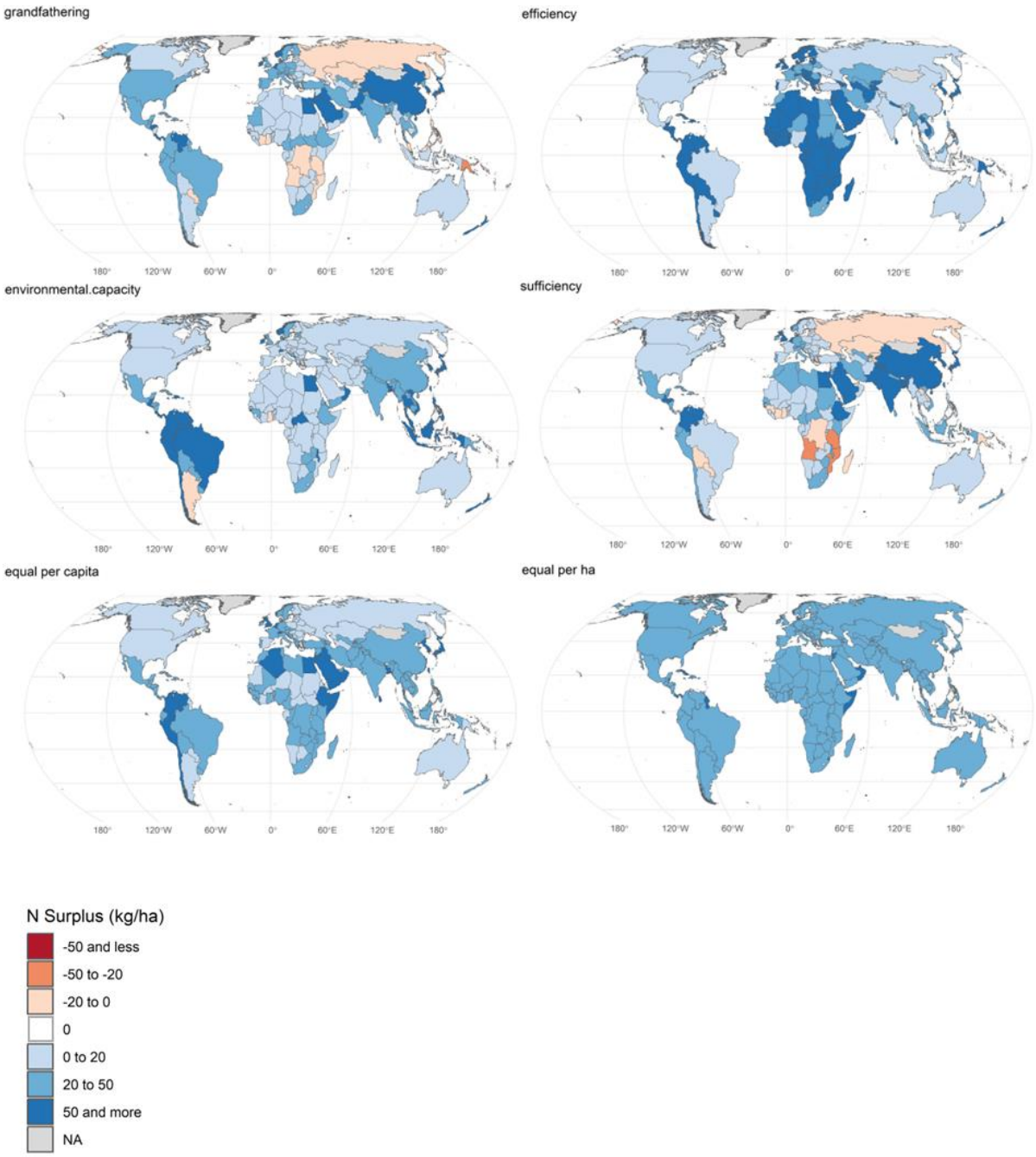


Figure 8. Map of the targeted nitrogen surplus (kg/ha/yr) in each country according to the grandfathering, efficiency, environmental capacity, sufficiency, equal per capita and equal per ha scenarios to distribute the global budget of nitrogen surplus; assuming the area harvested stays unchanged compared to the baseline. The values plotted here have been aggregated per country across crop groups.

Implementing the scenarios described above, which all lead to a 50% reduction of nitrogen surplus at the global level, revealed large differences in the distribution of the remaining N surplus between countries/ regions. For example, while under the environmental capacity scenario the targeted nitrogen surplus, both when looking at

ratios (N kg/ha/yr) and total values (N Mt/yr), is comparably low in many regions of the world, under the grandfathering scenario the targeted nitrogen surplus is high in a few countries including China (CHN, Fig.9, Mt, Fig. 8, N kg/ha/yr), the Netherlands and Norway (Fig.8, N kg/ha/yr), and under the efficiency scenario the targeted nitrogen surplus is high in the European Union (EU27, Fig. 9, N Mt/yr). Examining individual crop groups reveals that primary cereals and, in some countries, especially under the grandfathering and sufficiency scenarios, primary oil crops receive large shares of nitrogen surplus (Fig. 9, N Mt/yr). Assuming similar shares of nitrogen surplus related to the production of feed than in the baseline data, reveals that while total targeted nitrogen surplus related to the production for feed is particularly high in China, the relative shares of nitrogen surplus associated with the production of feed versus food & others are particularly high in countries and regions such as the USA, Brazil, but also the European Union (Fig. 10, 11, N Mt/yr).

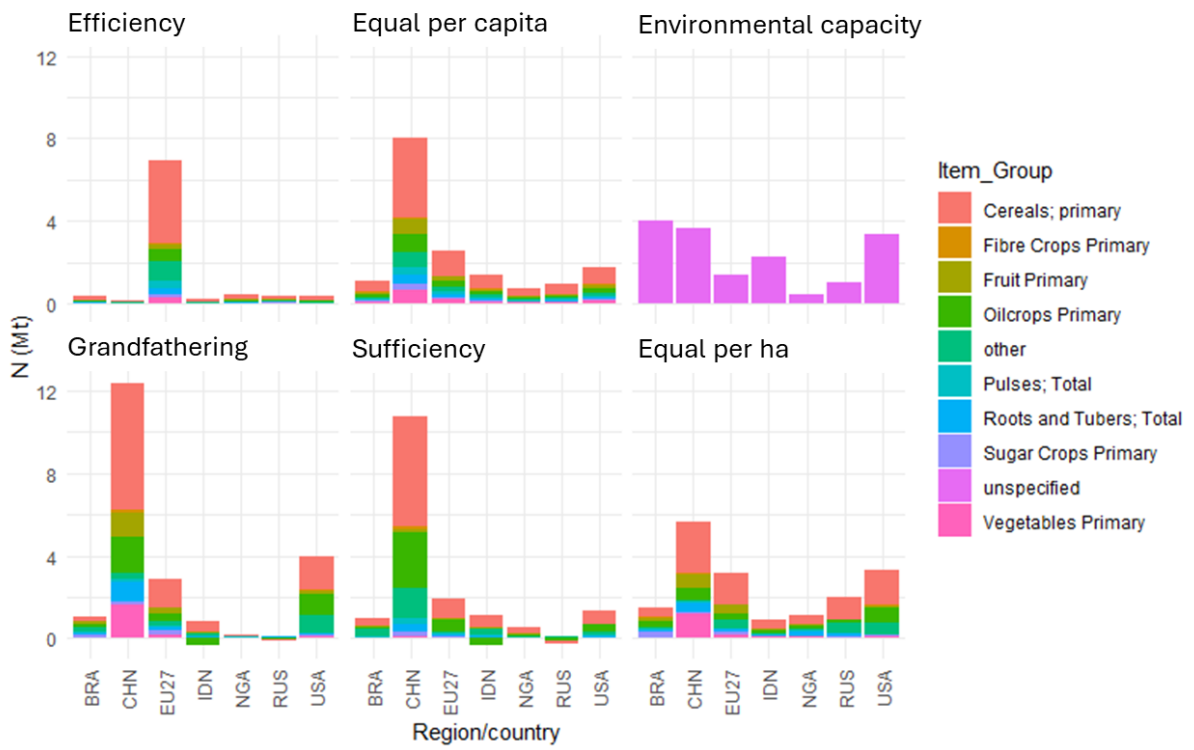


Figure 9. Targeted nitrogen surplus (Mt/yr) for different crop groups and seven example regions/ countries according to the efficiency, equal per capita, environmental capacity, grandfathering, sufficiency, and equal per hectare scenarios to distribute the global budget of nitrogen surplus. Note that data utilised for the environmental capacity scenario did not provide information on specific crops.

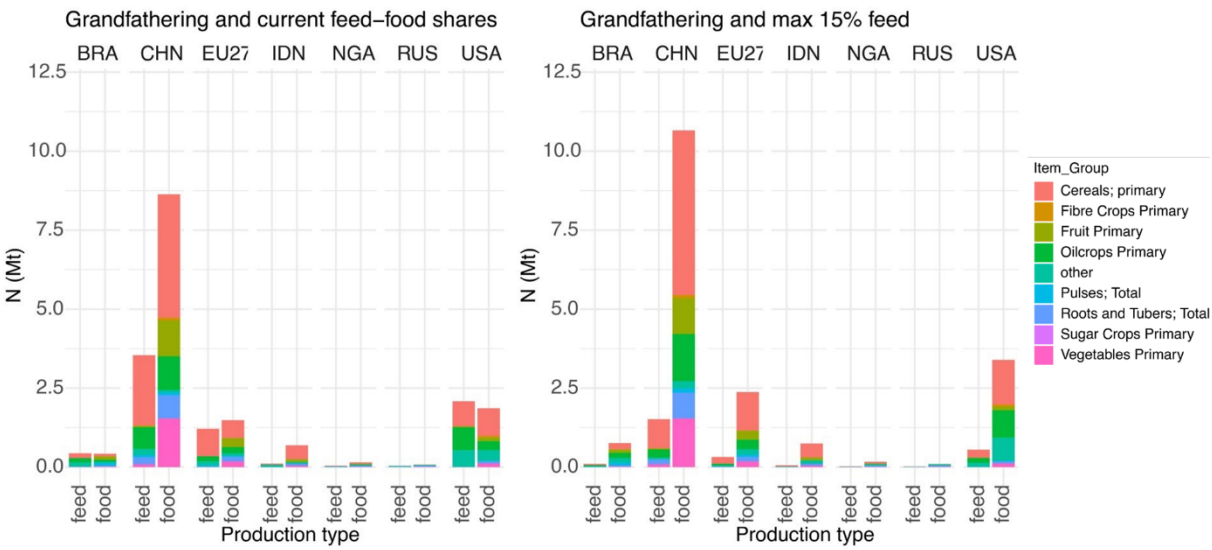


Figure 10. Two example scenarios of how to distribute a country's targeted nitrogen surplus (Mt/yr) between the production of crops for feed and food nested within the grandfathering scenario to distribute the global budget between countries. Shown for seven example countries/ regions. Left: the nitrogen surplus is allocated to the production of feed and food according to current shares. Right: the nitrogen surplus is allocated to the production of feed and food according to current shares, but the share allocated to feed is capped at a maximum of 15%.

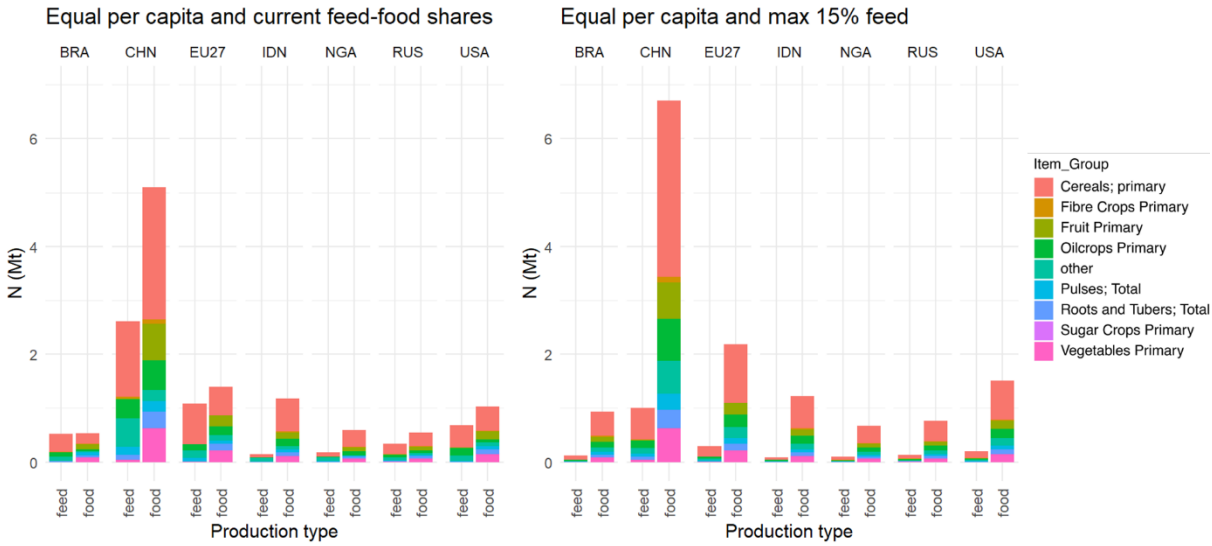


Figure 11. Two example scenarios of how to distribute a country's targeted nitrogen surplus (Mt/yr) between the production of crops for feed and food nested within the equal per capita scenario to distribute the global budget between countries. Shown for seven example countries/regions. Left: the nitrogen surplus is allocated to the production of feed and food according to current shares. Right: the nitrogen surplus is allocated to the production of feed and food according to current shares, but the share allocated to feed is capped at a maximum of 15%.

Table 8. crop groups considered for downscaling KMGBF target 7

Crop group	FAOSTAT item code and name (share)
Cereals; primary	15 Wheat; 27 Rice; 44 Barley; 56 Maize corn; 71 Rye; 75 Oats; 79 Millet; 83 Sorghum; 89 Buckwheat; 92 Quinoa; 94 Fonio; 97 Triticale; 101 Canary seed; 103 Mixed grain; 108 Cereals n.e.c.
Fibre Crops Primary	328 Seed cotton, unginned (0.35); 777 True hemp, raw or retted; 780 Jute, raw or retted; 782 Kenaf; and other textile bast fibres, raw or retted; 788 Ramie, raw or retted; 789 Sisal, raw; 800 Agave fibres, raw, n.e.c.; 809 Abaca, manila hemp, raw; 821 Other fibre crops, raw, n.e.c.
Fruit Primary	461 Locust beans carobs; 486 Bananas; 489 Plantains and cooking bananas; 490 Oranges; 495 Tangerines; mandarins; clementines; 497 Lemons and limes; 507 Pomelos and grapefruits; 512 Other citrus fruit; n.e.c.; 515 Apples; 521 Pears; 523 Quinces; 526 Apricots; 530 Sour cherries; 531 Cherries; 534 Peaches and nectarines; 536 Plums and sloes; 541 Other stone fruits; 544 Strawberries; 547 Raspberries; 549 Gooseberries; 550 Currants; 552 Blueberries; 554 Cranberries; 558 Other berries and fruits of the genus vaccinium n.e.c.; 560 Grapes; 567 Watermelons; 568 Cantaloupes and other melons; 569 Figs; 571 Mangoes; guavas and mangosteens; 572 Avocados; 574 Pineapples; 577 Dates; 587 Persimmons; 591 Cashewapple; 592 Kiwi fruit; 600 Papayas; 603 Other tropical fruits; n.e.c.; 619 Other fruits; n.e.c.
Oilcrops Primary	236 Soya beans; 242 Groundnuts, excluding shelled; 249 Coconuts, in shell; 254 Oil palm fruit; 260 Olives; 263 Karite nuts sheanuts; 265 Castor oil seeds; 267 Sunflower seed; 270 Rape or colza seed; 275 Tung nuts; 280 Safflower seed; 289 Sesame seed; 292 Mustard seed; 296 Poppy seed; 299 Melonseed; 328 Seed cotton; unginned (0.63); 333 Linseed;

	336 Hempseed; 339 Other oil seeds, n.e.c.
Pulses; Total	176 Beans, dry; 181 Broad beans and horse beans, dry; 187 Peas, dry; 191 Chickpeas, dry; 195 Cow peas, dry; 197 Pigeon peas, dry; 201 Lentils, dry; 203 Bambara beans, dry; 205 Vetches; 210 Lupins; 211 Other pulses n.e.c.
Roots and Tubers; Total	116 Potatoes; 122 Sweet potatoes; 125 Cassava, fresh; 135 Yautia; 136 Taro; 137 Yams; 149 Edible roots and tubers with high starch or inulin content, n.e.c., fresh
Sugar Crops Primary	156 Sugar cane; 157 Sugar beet; 161 Other sugar crops, n.e.c.
Vegetables Primary	367 Asparagus; 372 Lettuce and chicory; 373 Spinach; 388 Tomatoes; 393 Cauliflowers and broccoli; 394 Pumpkins, squash and gourds; 397 Cucumbers and gherkins; 399 Eggplants aubergines; 401 Chillies and peppers, green Capsicum spp. and Pimenta spp.; 402 Onions and shallots, green; 403 Onions and shallots, dry excluding dehydrated; 406 Green garlic; 414 Other beans, green; 417 Peas, green; 420 Broad beans and horse beans, green; 423 String beans; 426 Carrots and turnips; 430 Okra; 446 Green corn maize; 449 Mushrooms and truffles; 463 Other vegetables, fresh n.e.c.
other	216 Brazil nuts, in shell; 217 Cashew nuts, in shell; 220 Chestnuts, in shell; 221 Almonds, in shell; 222 Walnuts, in shell; 223 Pistachios, in shell; 224 Kola nuts; 225 Hazelnuts, in shell; 226 Areca nuts; 234 Other nuts (excluding wild edible nuts and groundnuts), in shell, n.e.c.; 311 Kapokseed in shell; 459 Chicory roots; 656 Coffee, green; 661 Cocoa beans; 667 Tea leaves; 671 Maté leaves; 677 Hop cones; 687 Pepper Piper spp., raw; 689 Chillies and peppers, dry Capsicum spp., Pimenta spp., raw; 692 Vanilla, raw; 693 Cinnamon and cinnamon-tree flowers, raw; 698 Cloves

	whole stems, raw; 702 Nutmeg, mace, cardamoms, raw; 711 Anise, badian, coriander, cumin, caraway, fennel and juniper berries, raw; 720 Ginger, raw; 723 Other stimulant, spice and aromatic crops, n.e.c.; 748 Peppermint, spearmint; 754 Pyrethrum, dried flowers; 778 Kapok fibre, raw; 826 Unmanufactured tobacco; 836 Natural rubber in primary forms; 636 Maize for Forage& Silage; 637 Sorghum for Forage& Silage; 638 Rye Grass for Forage& Silage; 639 Grasses nes for Forage& Silage; 640 Clover for Forage& Silage; 641 Alfalfa for Forage& Silage; 642 Green Oilseeds for Fodder; 643 Leguminous nes for Forage& Silage; 644 Cabbage for Fodder; 645 Mixed Grasses& Legumes; 646 Turnips for Fodder; 647 Beets for Fodder; 648 Carrots for Fodder; 649 Swedes for Fodder; 651 Forage Products nes; 655 Vegetables& Roots, Fodder; 773 Flax Fibre and Tow

§5 Target 16: Enable Sustainable Consumption Choices to Reduce Waste and Overconsumption

Target 16 of the KMGBF focusses on consumption as a leverage point for reducing pressures on nature and calls for *"[…] by 2030, reduce the global footprint of consumption in an equitable manner, including through halving global food waste, significantly reducing overconsumption and substantially reducing waste generation, […]"* (CBD, 2022a). From this wording it becomes clear that a main focus of this target is reducing overconsumption. For our data work the current framing poses two challenges: (1) besides the provision on halving food waste, no quantitative target is stated, as defining what constitutes overconsumption is clearly contested. And (2) the "global footprint of consumption" can be made up of many different impact and product categories, many of which not directly related to agri-food chains. To be able to provide results that can be discussed and interpreted within the framework of our pathways and the overall setup of RAINFOREST, we narrowed down and specified the work as follows. For (2) we chose to focus on the cropland area footprint of food consumption as an example of a consumption

footprint with clear links to the agri-food system. With regards to (1), and to being able to perform a quantitative exercise, we set the target that the global footprint is reduced by 25% (i.e. to 75% of the current level). The implemented translations of distributive justice principles will be applicable and can be implemented for different footprint indicators and for different reduction target levels.

It is important to stress that the target as formulated by the CBD specifies footprints of consumption (such as the cropland area footprint in our example). However, the magnitude of such footprints is not only determined by consumption patterns but also dependent on production techniques and conditions. For instance, for area footprints, if output per unit land is higher, the area footprint per consumed unit will be lower. In certain situations, results might point to potential for production-side measures as meaningful way to reduce the footprint of consumption. By linking processes from production, through trade to consumption the quantitative downscaling exercise can contribute and highlight the potential of different consumption footprint reduction options in different contexts.

§5.1 Indicator and data

We focus on cropland area in terms of hectares cropland harvested (Vanham et al., 2023). Globally, croplands occupy about 13% of the Earth's surface area. They are typically located on fertile lands with high natural productivity and high biodiversity value. Conversion from natural lands to croplands hold an outsized role in human impacts on ecosystems and biodiversity (Kastner et al, 2021, Semenchuk et al. 2022).

In line with the target's focus on consumption, we focus on changes in per-capita footprints to compare countries and the impact of different distributive justice considerations, with the 25% reduction of overall footprint to be reached at the global level. We distinguish between different food categories (Table 9) and whether the consumed food is produced domestically or imported. For imports we further distinguish two categories, based on the distance between the country of origin and the country where the food is consumed. For this we employ CEPII's weighted country-by-country distance matrix (Mayer and Zignago, 2011). We distinguish between imports originating from countries less (or exactly) 2500 km from the country of food consumptions and those with a distance larger than 2500 km.

Cropland footprint quantification followed the approach outlined in Kastner et al. (2011, 2014) and represents updated data from (Vanham et al. 2023). This also includes a quantification of how much of the cropland products consumed in each country are used for food purposes (either from domestic cropland or through imports), either directly or via feed use and conversion into animal-based food. To link this to food consumption, we aligned it with caloric food supply in each country, aggregated into the same categories. Both the cropland footprint data and the food supply data are based on data in the FAOSTAT database (FAO, 2025), ensuring consistency between the footprint and food supply data. To translate values from national totals to per capita values we used population numbers from FAOSTAT as well (FAO, 2025). For both, cropland footprint and food supply data the baseline refers to a five-year average around the year 2020.

Additionally, for implementing specific principles on how to reduce the cropland footprint of food consumption we rely on the following data source: country specific information on biodiversity impacts of crop and livestock production based on a countryside-Species Area Relationship modelling approach (Bidoglio et al. under review), which extends previous work from Semenchuk et al. (2022) and Chaudhary and Brooks (2018). These data provide information on two aspects of vertebrate biodiversity loss: the global impact metric is an indicator of potential species loss at the global level, i.e. global extinctions (Chaudhary and Brooks, 2018), and is sensitive to species range sizes and current threat statuses. The local metric is an indicator of the number of species disappearing at a local landscape level (here defined as pixels of 10 km by 10 km; see Semenchuk et al. 2023). As a central focus of the RAINFOREST project is on biodiversity, we use this indicator as an example for approaches implementing but also present implication on biodiversity for all scenarios. On the food supply side, we use data on the proposed planetary diet (EAT Lancet diet) as translated into kcal food demand by Hirvonen et al. (2020). In addition to the values derived from this publication, we added an allowance of 10 kcal / cap / day for simulants (coffee, chocolate, tea) which are not covered in the EAT Lancet diet (the value is close to the present global average level).

§5.2 Implementing different ways to reduce the cropland area footprint of food consumption by 25%

In the following, after briefly introducing the results for the baseline calculations, we run through the implemented scenarios one after the other, briefly outlining the chose approach, their alignment with principles of distributional justice and with the VITAL-FOOD-PATHS framework.

Figure 13 presents the **Baseline 2020** situation, used for the downscaling exercise. We show per-capita results for the EU 27, large countries from different world regions, and the global average. We see that in terms of cropland area footprint, the average per capita value for the EU 27 is slightly higher than the global average, and that a large share of the footprint occurs far away from the EU. Food availability is higher than the global average as well, containing a high amount of animal products. For biodiversity impacts the footprint of the EU 27 are below global average, mainly driven by the fact that domestic lands are lower in biodiversity value (especially with the global impact indicator, i.e. lower species richness of vertebrate species and less endemic and endangered species) than many other regions. The largest share of biodiversity impacts is associated with imports. Figure 13 (and also the other subsequent cropland area footprint bar charts) also shows the target values for a reduction of the cropland area footprint, giving 2 versions: (a) a reduction towards 75% of the current global average, which would reflect an egalitarian approach towards reaching the global target or (b) a reduction towards 75% of the current individual country values, in line with the grandfathering principle.

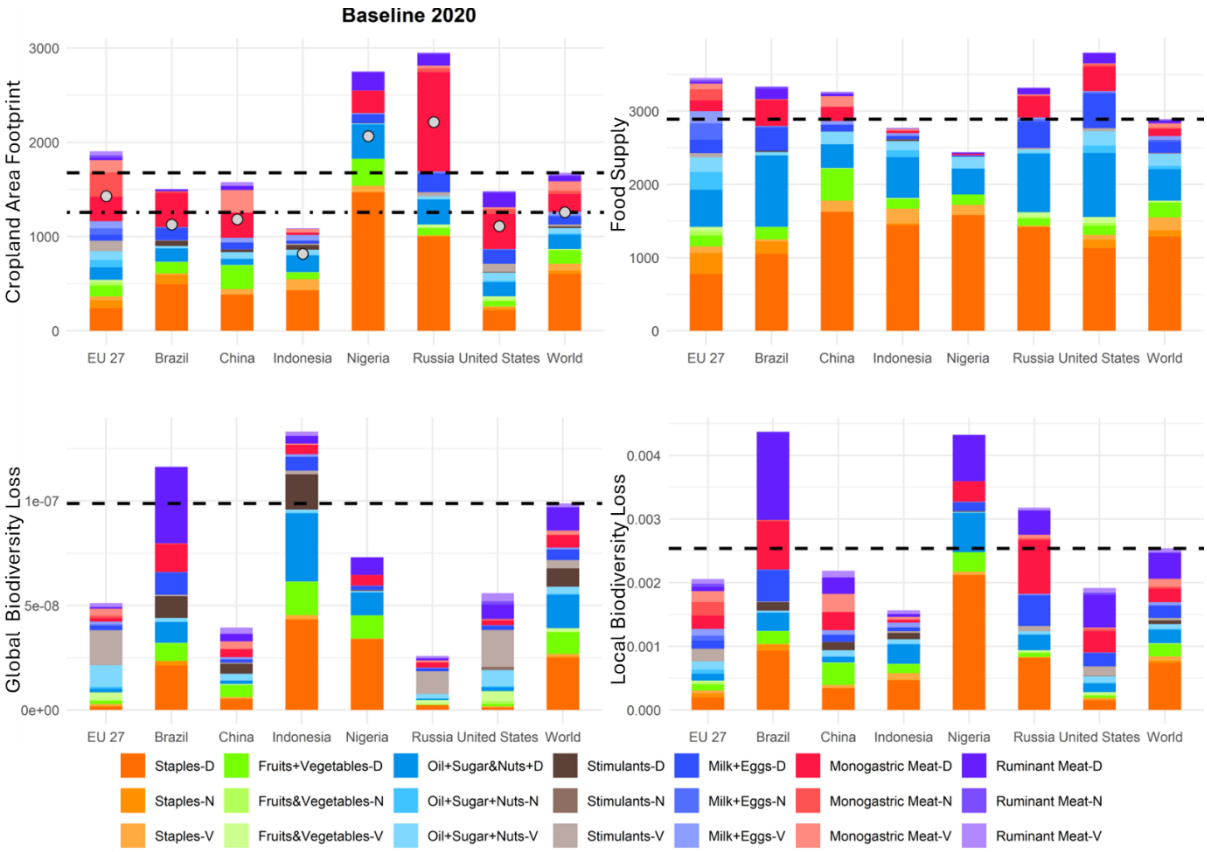


Figure 12. Baseline 2020 values for the downscaling of the cropland area footprint of food consumption for the EU 27, selected countries and the global average. Values refer to a five-year average around the year 2020. Top left: cropland area footprint of food consumption in m^2 of cropland area harvested per capita and year. Top right: food supply in kcal per capita and day. Bottom left: potential global loss of terrestrial vertebrate species in number of species per capita. Bottom right: potential local loss of terrestrial vertebrate species in number of species disappearing from a 100 km^2 landscape per capita. For the aggregation of crops into the presented categories, please refer to Table 9. The suffixes next to the food categories refer to: "D" domestic production. "N" imports from countries less than 2500 km away, "V" imports from countries more than 2500 km away. Dashed lines represent the overall global average in 2020 for the respective variable. For the cropland area footprint, the dot-and-dashed line represents the reduction of this global average by 25% and the gray points represent a 25% reduction of the country-specific value in 2020.

Figure 13 provides four global maps for the **Baseline 2020**, highlighting per capita cropland area footprints of food consumption, the share of imports in the footprints, the overall per capita food supply and the share of staples in food supply.

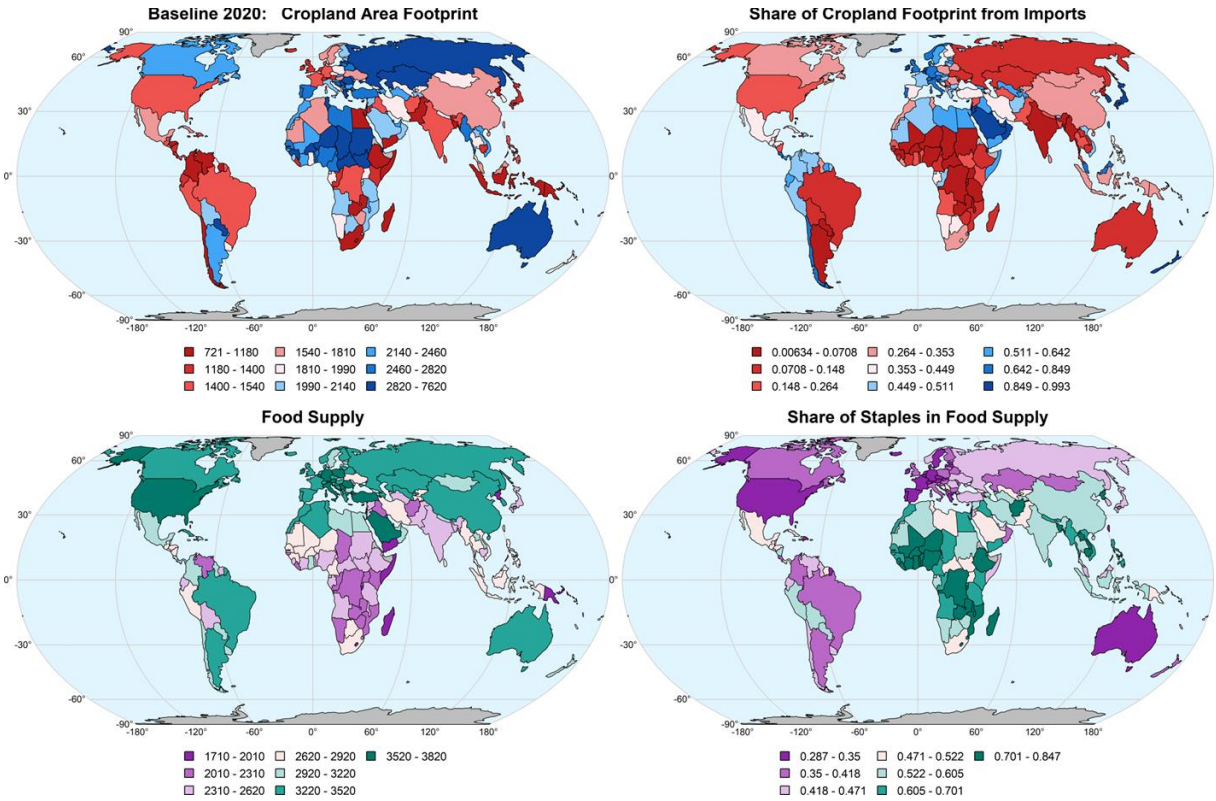


Figure 13. World maps of Baseline 2020 values for the downscaling of the cropland area footprint of food consumption. Values refer to a five-year average around the year 2020. Top left: cropland area footprint of food consumption in m² of cropland area harvested per capita and year. Top right: share of cropland footprint met by imports. Bottom left: total food supply in kcal per capita and day. Bottom right: share of food supply met by the staple food category (see Table 9). Countries are grouped in quantiles, with the countries close to global median value presented in a neutral color; values with increasing intensity imply increasing divergence of the respective country from this median value.

Starting from these global baseline values, we implemented these different scenarios:

Area Efficiency: This scenario is based on the idea of the most efficient allocation of land in terms of area required per unit of (in this case caloric) output. For its implementation, we assume that lands with the lowest area efficiency per food category (i.e. kcal food per m²) are taken out of use. This implies that the 75% of cropland (per category) with the highest area efficiency remains productive. Food supply is kept constant in comparison to the baseline, implying increases in crop yields are necessary. In addition, countries who currently exhibit a very low area efficiency would "lose" much of their domestic cropland and subsequently their food supply. In this scenario we compensate for this by allowing additional imports for

these countries from lands with higher area efficiencies. These additional imports are visualized as additional imports from very far away. The required yield increases to keep food supply are around 9% across all crops (clearly below the 25% of reduced cropland use), ranging from 4% for stimulants to 15% for fruits and vegetables. This scenario would align well with the thinking behind the International Market Innovation Pathway.

Environmental Capacity: Globally, lands with the highest "biodiversity cost" per unit of food supplied are taken out of production, in our implementation regardless across all categories. In contrast to the previous scenario, we do not calculate how much crop yields would have to increase to keep food supply constant but rather highlight how much food supply would become unavailable by freeing up lands for biodiversity conservation and where it would this food supply would be "missing". In this way we show that the downscaling approach can be used in different ways as conversation starter for discussions around costs and benefits of actions towards biodiversity targets. Note also that we chose a single biodiversity indicator for the implementation of this approach. A more holistic approach with regards to environmental capacity would have to include different environmental aspects and consider trade-offs between them. This scenario could be well aligned with nature for nature thinking and the Global Sustainability Orchestration pathway.

Localist: in line with highlighting the use of the downscaling approach to showcase the potential and limitations of strategies discussed in relation to the global food system, we implemented a simple Localist scenario. For the implementation of this "discussion starter", we simply cut out all food supply from imports, freeing up all areas currently used for export production. Making food supply chains shorter and food supply more local is an idea fitting well with a relational valuation of nature and the Local Commons Stewardship pathway.

Sufficiency: we assessed a scenario that implements the widely discussed EAT Lancet planetary diet framed as a Sufficiency scenario. In this context, we highlight that the downscaling approach can also be employed in a stepwise manner, enabling discussions on the potential contribution of different strategies to reach a target. As a first step, we modified food supply in each country to match the composition of the EAT Lancet diet and kept all the other factors constant in a **Sufficiency ceteris**

paribus scenario (Figures 21 and 22). For many countries in the Global North the results show that such a change in dietary patterns is already sufficient to reach the national targets set by the grandfathering and egalitarian principles (see above). However, at the global level, the cropland area footprint would remain virtually unchanged, because in countries with a poor nutritional situation and low crop yield (for instance, Nigeria) the changed towards the EAT Lancet diet would imply a substantial increase in cropland requirements, i.e. the implementation of this scenario fails to reach the global level target. Therefore, in such a stepwise approach, the results can point towards the need for combining dietary change with other strategies. For instance, reducing using part of the freed-up footprint of the EU (and similar situations) for additional export production to export products for highly biodiverse countries (similar to the Area Efficiency scenario) could achieve the global target while also supplying the EAT Lancet diet at a global level (not shown). For our implementation of the **Sufficiency** scenario, we implemented another strategy: yield increases in countries with footprints exceeding their country specific (grandfathering based) targets (grey dots in the figures). This could then provide information on what level of intensification levels would be required where to both supply the EAT Lancet diet and reach the cropland area footprint target. With regards to the developed pathways, a transition towards a planetary health diet could fit into the thinking of the Global Sustainability Orchestration pathway, while the idea that having a healthy and equitable diet also fits the thinking of the Local Common Stewardship pathway.

In the Area Efficiency scenario (Figure 15 and 16) the EU would retain a high cropland footprint, owing to unchanged food consumption patterns and little cropland areas supplying the EU footprint within the lower quarter of lands in terms of area efficiency. Countries whose footprints rely on large areas with low area efficiency, would see large reduction in their cropland footprints, however, rely much more on imports under assumption of this scenario (for instance, Nigeria and Russia).

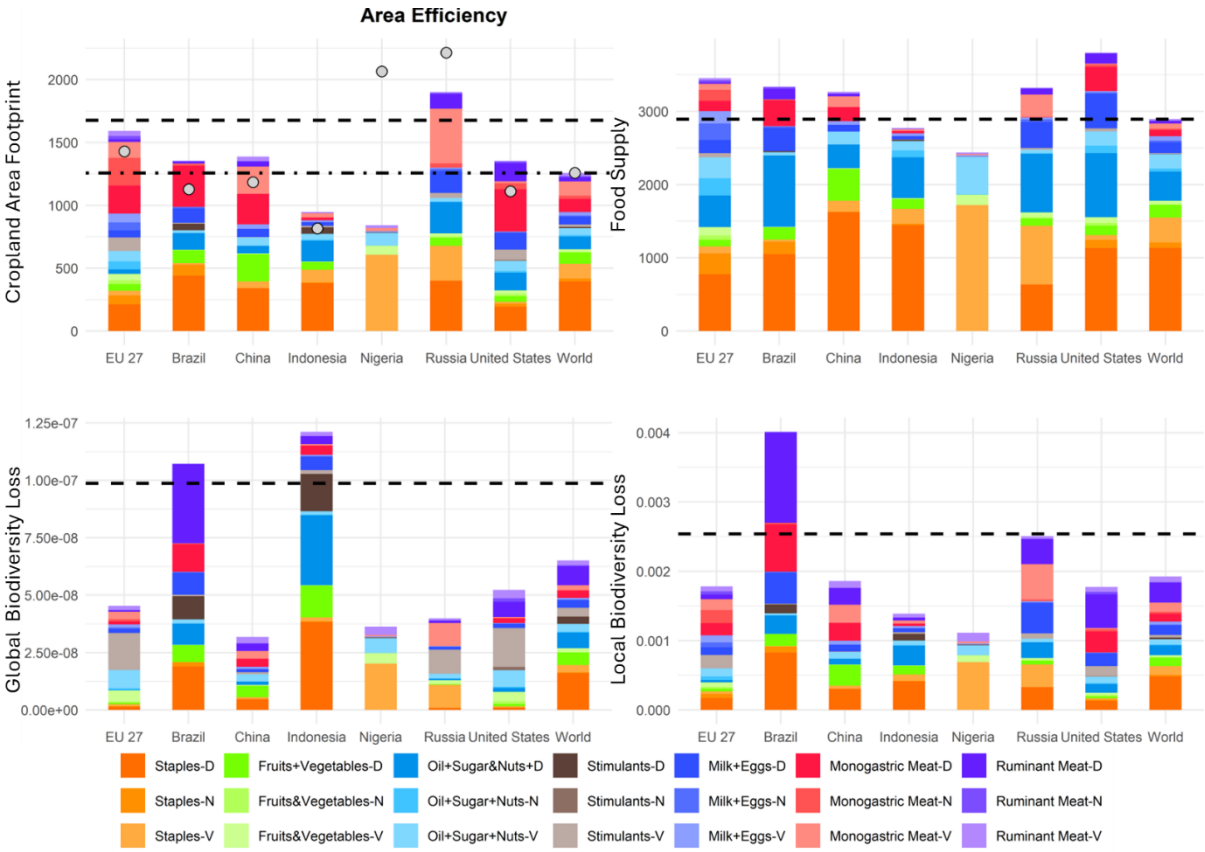


Figure 15. Results of the Area Efficiency scenario for the downscaling of the cropland area footprint of food consumption for the EU 27, selected countries and the global average. Values refer to a five-year average around the year 2020. Top left: cropland area footprint of food consumption in m² of cropland area harvested per capita and year. Top right: food supply in kcal per capita and day. Bottom left: potential global loss of terrestrial vertebrate species in number of species per capita. Bottom right: potential local loss of terrestrial vertebrate species in number of species disappearing from a 100 km² landscape per capita. For the aggregation of crops into the presented categories, please refer to Table 9. The suffixes next to the food categories refer to: "D" domestic production. "N" imports from countries less than 2500 km away, "V" imports from countries more than 2500 km away. Dashed lines represent the overall global average in 2020 for the respective variable. For the cropland area footprint, the dot-and-dashed line represents the reduction of this global average by 25% and the gray points represent a 25% reduction of the country-specific value in 2020.

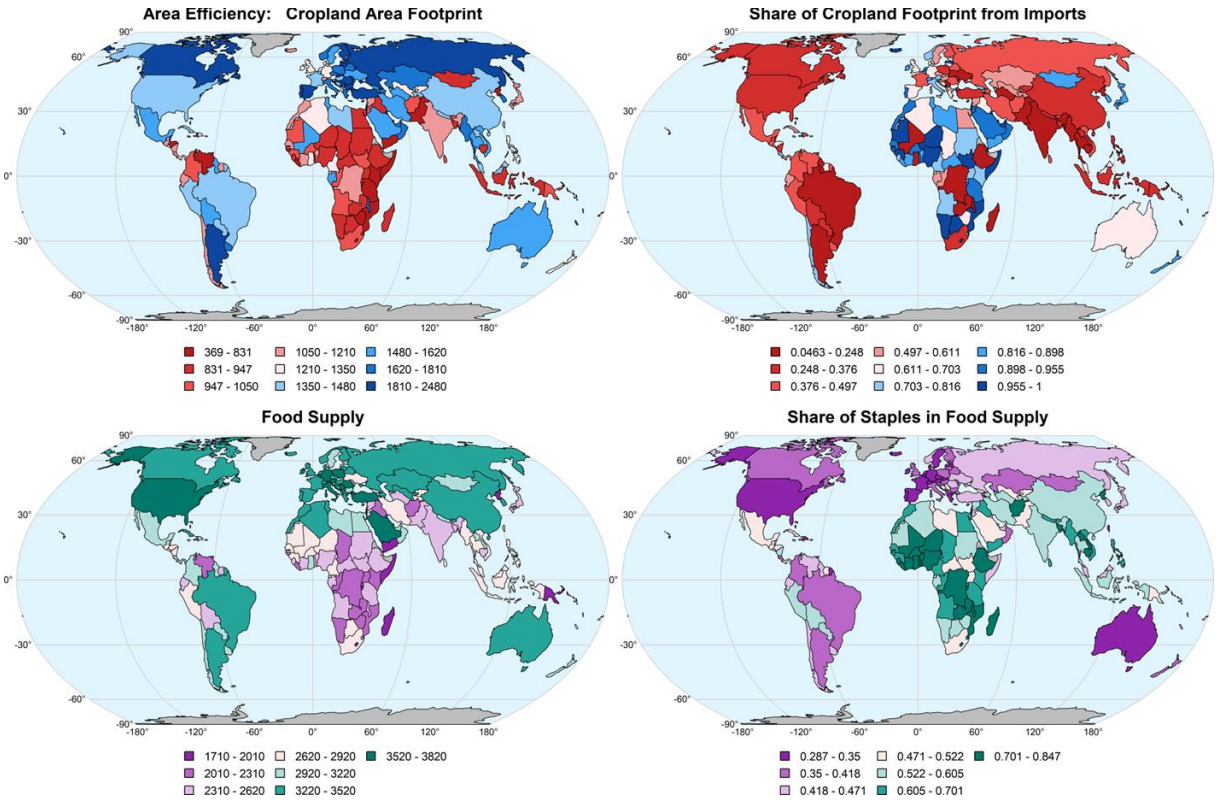


Figure 14. World maps of the Area Efficiency scenario for the downscaling of the cropland area footprint of food consumption. Values refer to a five-year average around the year 2020. Top left: cropland area footprint of food consumption in m^2 of cropland area harvested per capita and year. Top right: share of cropland footprint met by imports. Bottom left: total food supply in kcal per capita and day. Bottom right: share of food supply met by the staple food category (see Table 9). Countries are grouped in quantiles, with the countries close to global median value presented in a neutral color; values with increasing intensity imply increasing divergence of the respective country from this median value. Note that the resulting classes are defined by the distribution of within the specific scenario and will differ across scenarios.

Figure 17 highlights that in the Environmental Capacity scenario, reducing the global cropland footprint by 25% would reduce the number of terrestrial vertebrate species that are committed to extinction by about two thirds. In terms of food supply, the EU and countries like the USA but also China would still be at reasonable levels. At the same time, countries that have already a relatively low food supply and harbor very biodiverse ecosystems would have to rely on additional imports. In terms of food categories, reduction would occur especially with regards to animal products (and here especially products from ruminants, as the biodiversity costs include the impact of pastures) and stimulants, but also (tropical) fruits and

vegetables. The maps in Figure 18 confirm the picture of the bar charts, highlighting that many tropically countries, rich in biodiversity would have to rely more on imports in such a scenario to maintain sufficient food supply, while potentially countries in the Global North could further reduce parts of their food consumption to make lands available for exports.

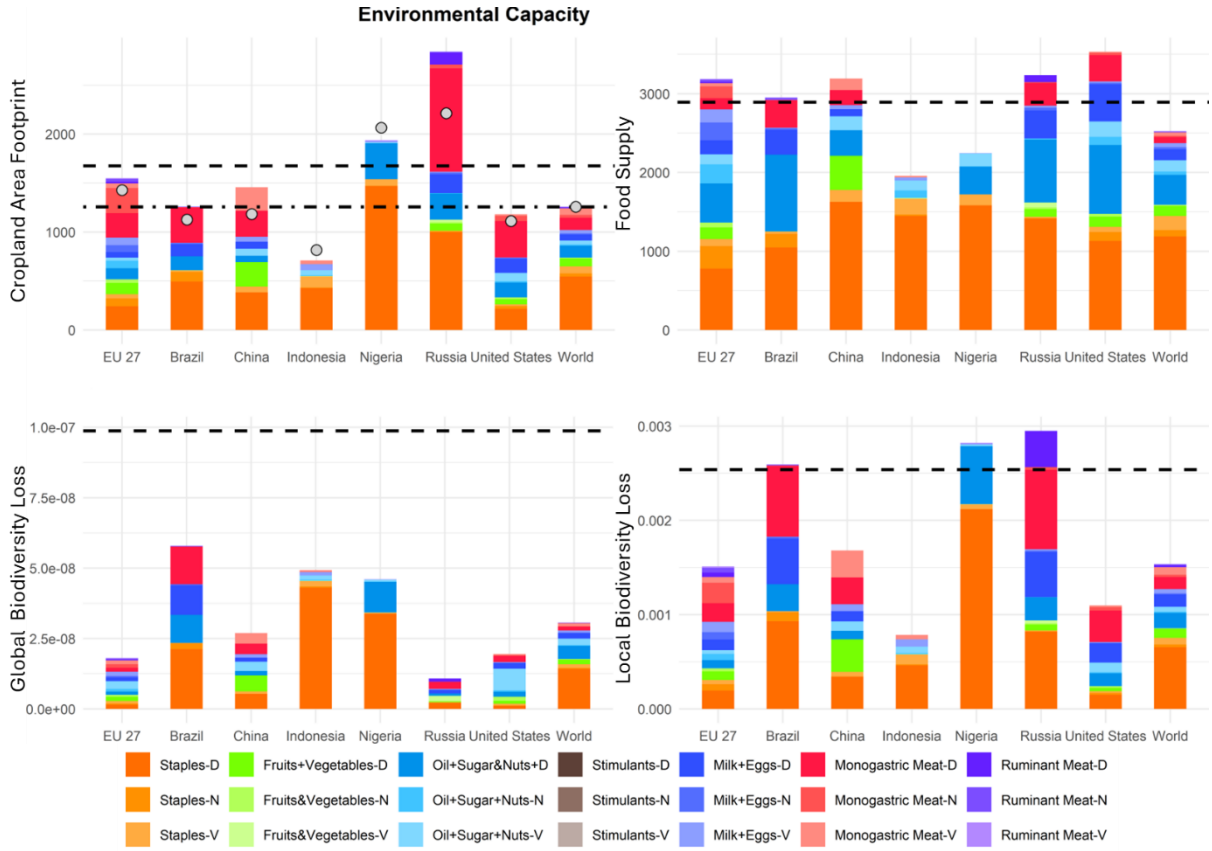


Figure 15. Results of the Environmental Capacity scenario for the downscaling of the cropland area footprint of food consumption for the EU 27, selected countries and the global average. Values refer to a five-year average around the year 2020. Top left: cropland area footprint of food consumption in m² of cropland area harvested per capita and year. Top right: food supply in kcal per capita and day. Bottom left: potential global loss of terrestrial vertebrate species in number of species per capita. Bottom right: potential local loss of terrestrial vertebrate species in number of species disappearing from a 100 km² landscape per capita. For the aggregation of crops into the presented categories, please refer to Table 9. The suffixes next to the food categories refer to: "D" domestic production. "N" imports from countries less than 2500 km away, "V" imports from countries more than 2500 km away. Dashed lines represent the overall global average in 2020 for the respective variable. For the cropland area footprint, the dot-and-dashed line represents the reduction of this global average by 25% and the gray points represent a 25% reduction of the country-specific value in 2020.

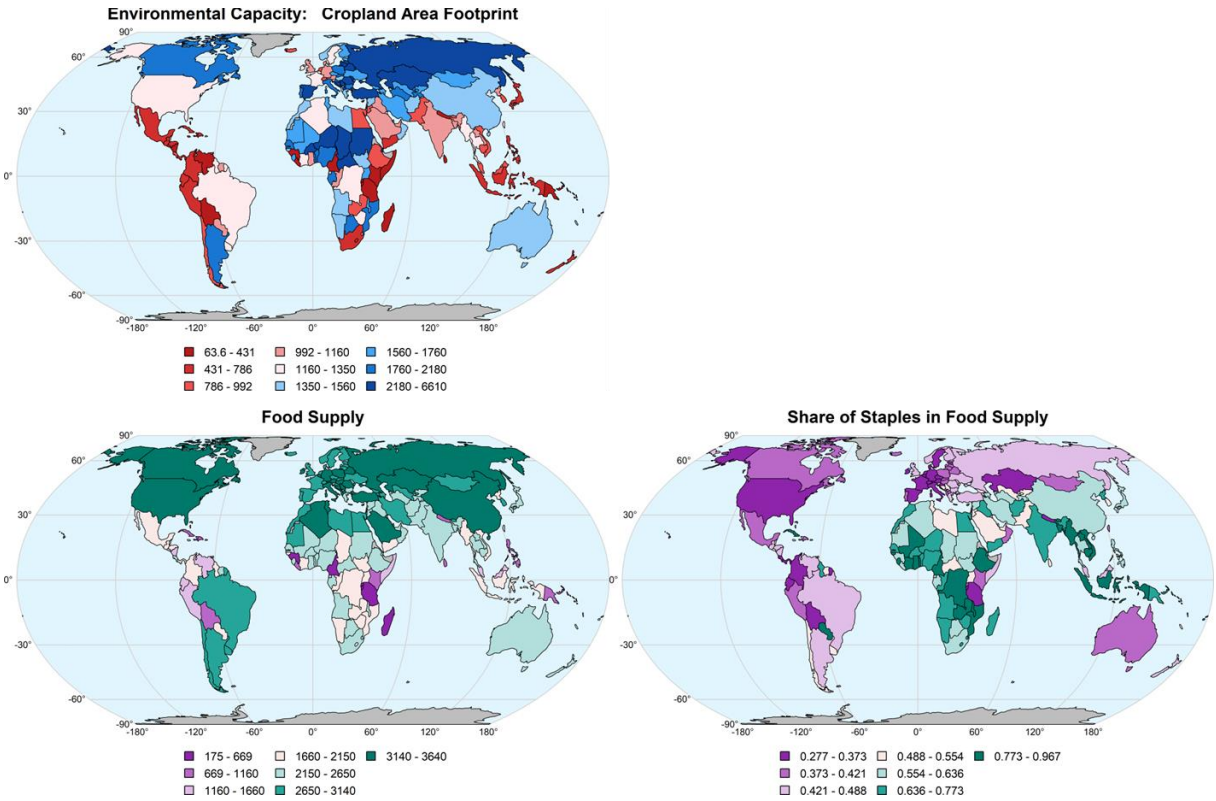


Figure 16. World maps of the Environmental Capacity scenario for the downscaling of the cropland area footprint of food consumption. Values refer to a five-year average around the year 2020. Top left: cropland area footprint of food consumption in m² of cropland area harvested per capita and year. Top right: share of cropland footprint met by imports – not shown as resulting reshuffling of trade was not in focus of this scenario. Bottom left: total food supply in kcal per capita and day. Bottom right: share of food supply met by the staple food category (see Table 8). Countries are grouped in quantiles, with the countries close to global median value presented in a neutral color; values with increasing intensity imply increasing divergence of the respective country from this median value. Note that the resulting classes are defined by the distribution of within the specific scenario and will differ across scenarios.

Figure 19 reveals that for the Localist scenario, at the global level, this almost exactly achieves the target or reducing the cropland area footprint of food consumption by 25% (also implying that at the global level it would not free up land currently used for exports to be used for domestic consumption if the target is to be met without additional changes). For countries that rely only in small portions on imported food, this changes little in their food availability. For the EU, however, whose members depend greatly on imported food, the Localist scenario, while greatly reducing its cropland footprint (far beyond the individual targets), it would also imply food supply below sufficient per capita values (below 2000 kcal per day). "Allowing" intra-EU trade would change this already, considerably, with food supply reaching reasonable levels in terms of calories (not shown). It would still remove food currently enjoyed in the EU that cannot be grown domestically (stimulants, tropical fruits) and would likely require changes in the diet to achieve a balanced nutrition around the year. In terms of global biodiversity impacts, Figure 19 reveals that the Localist scenario would only achieve modest reductions (less than the 25% area that is taken out of use). In addition, the maps in Figure 20 highlight that several countries would struggle greatly without food imports to supply food domestically, especially in environments with low suitability for large scale agriculture such as the Middle East).

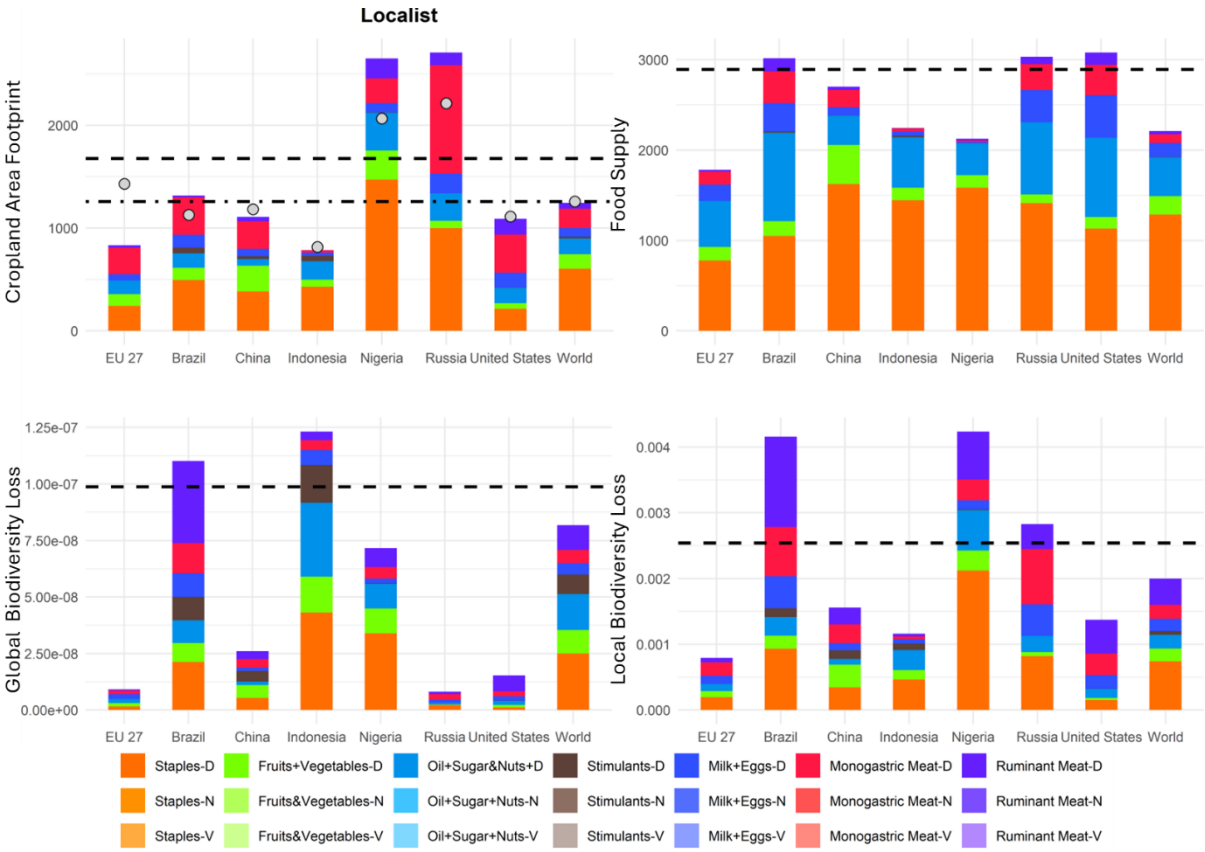


Figure 17. Results of the Localist scenario for the downscaling of the cropland area footprint of food consumption for the EU 27, selected countries and the global average. Values refer to a five-year average around the year 2020. Top left: cropland area footprint of food consumption in m² of cropland area harvested per capita and year. Top right: food supply in kcal per capita and day. Bottom left: potential global loss of terrestrial vertebrate species in number of species per capita. Bottom right: potential local loss of terrestrial vertebrate species in number of species disappearing from a 100 km² landscape per capita. For the aggregation of crops into the presented categories, please refer to Table 9. The suffixes next to the food categories refer to: "D" domestic production. "N" imports from countries less than 2500 km away, "V" imports from countries more than 2500 km away. Dashed lines represent the overall global average in 2020 for the respective variable. For the cropland area footprint, the dot-and-dashed line represents the reduction of this global average by 25% and the gray points represent a 25% reduction of the country-specific value in 2020.

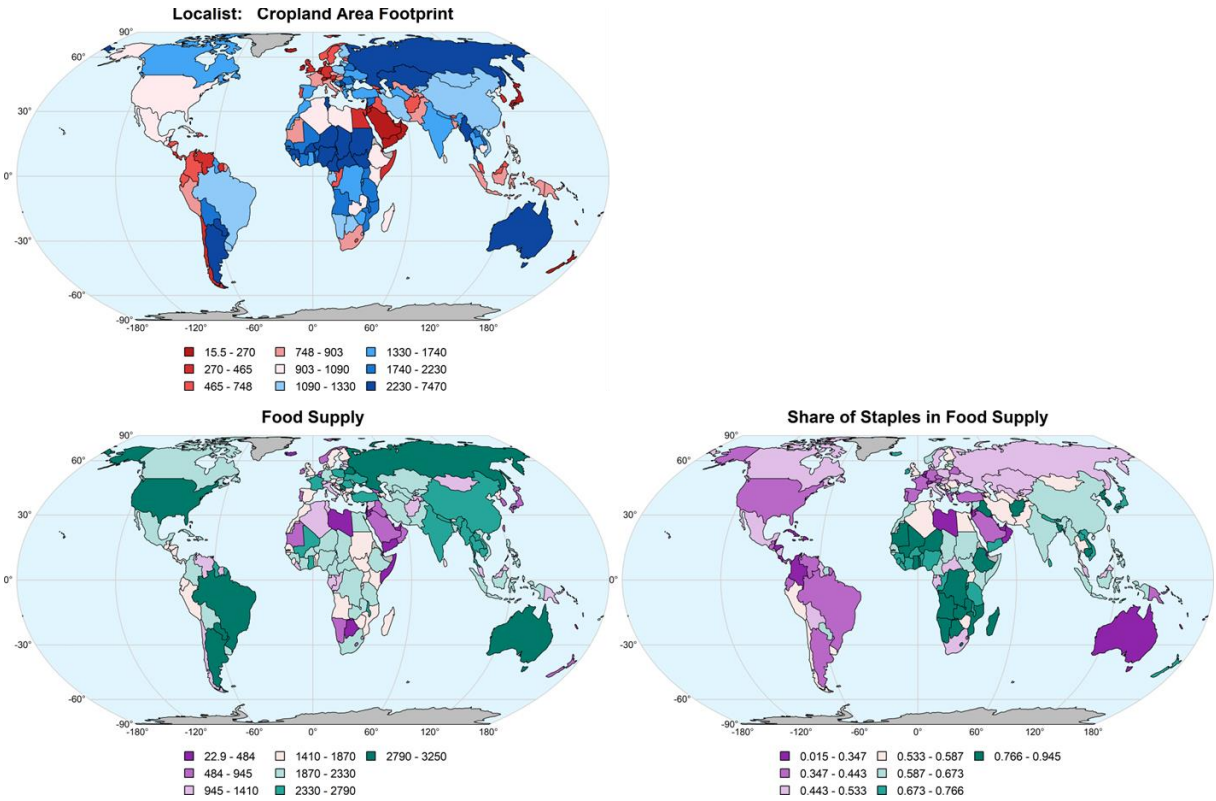


Figure 18. World maps of the Localist scenario for the downscaling of the cropland area footprint of food consumption. Values refer to a five-year average around the year 2020. Top left: cropland area footprint of food consumption in m^2 of cropland area harvested per capita and year. Top right: share of cropland footprint met by imports, not shown as this is by definition zero for all countries in this scenario. Bottom left: total food supply in kcal per capita and day. Bottom right: share of food supply met by the staple food category (see Table 9). Countries are grouped in quantiles, with the countries close to global median value presented in a neutral color; values with increasing intensity imply increasing divergence of the respective country from this median value. Note that the resulting classes are defined by the distribution of within the specific scenario and will differ across scenarios.

For the **Sufficiency ceteris paribus** scenario Figures 21 and 22 show that many countries in the Global North such a change in dietary patterns is sufficient to reach the targets set by the grandfathering and um egalitarian principles. For the EU, this would almost halve the current cropland area footprint. However, at the global level, the cropland area footprint would remain virtually unchanged, because in countries with a poor nutritional situation and low crop yields (for instance, Nigeria) the changed towards the EAT Lancet diet would imply a substantial increase in cropland requirements. Biodiversity loss would even increase in such a ceteris paribus scenario.

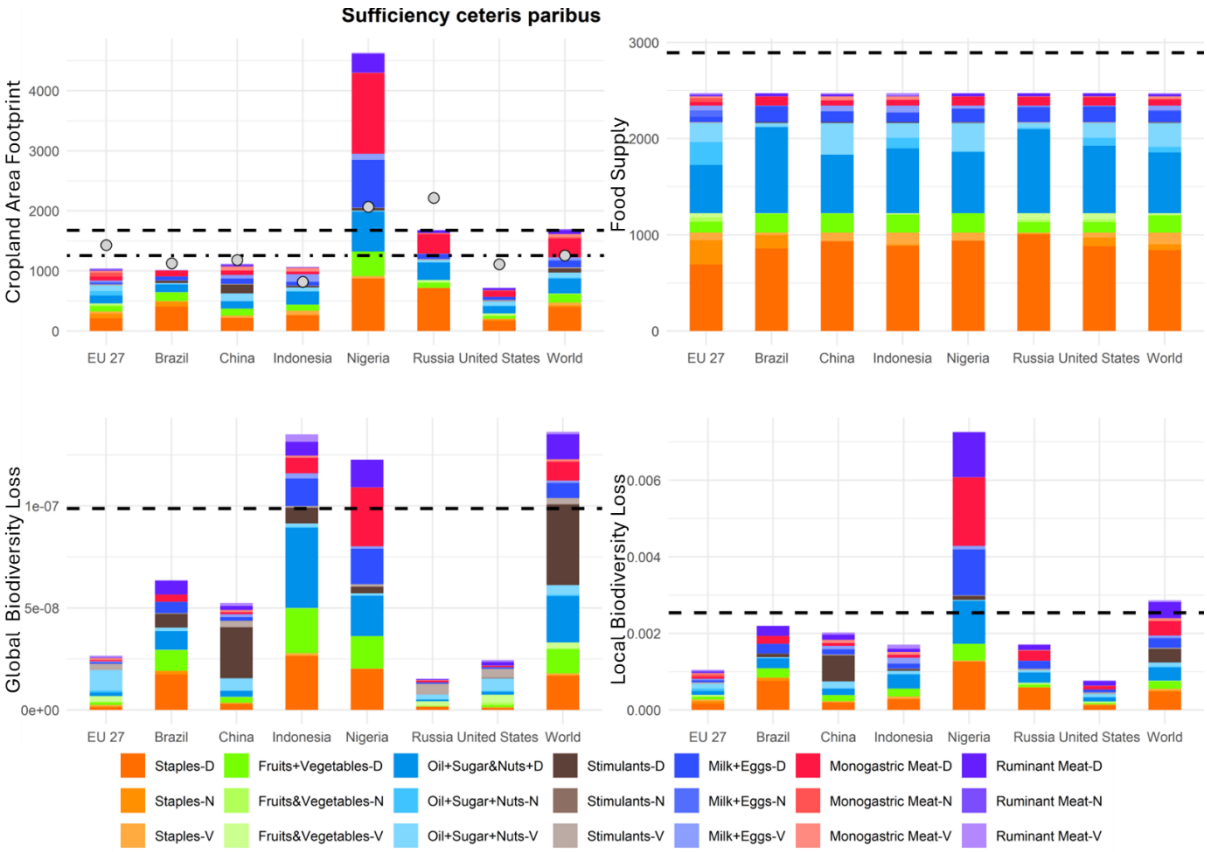


Figure 19. Results of the Sufficiency ceteris paribus scenario (assuming everything else constant) for the downscaling of the cropland area footprint of food consumption for the EU 27, selected countries and the global average. Values refer to a five-year average around the year 2020. Top left: cropland area footprint of food consumption in m² of cropland area harvested per capita and year. Top right: food supply in kcal per capita and day. Bottom left: potential global loss of terrestrial vertebrate species in number of species per capita. Bottom right: potential local loss of terrestrial vertebrate species in number of species disappearing from a 100 km² landscape per capita. For the aggregation of crops into the presented categories, please refer to Table 9. The suffixes next to the food categories refer to: "D" domestic production. "N" imports from countries less than 2500 km away, "V" imports from countries more than 2500 km away. Dashed lines represent the overall global average in 2020 for the respective variable. For the cropland area footprint, the dot-and-dashed line represents the reduction of this global average by 25% and the gray points represent a 25% reduction of the country-specific value in 2020.

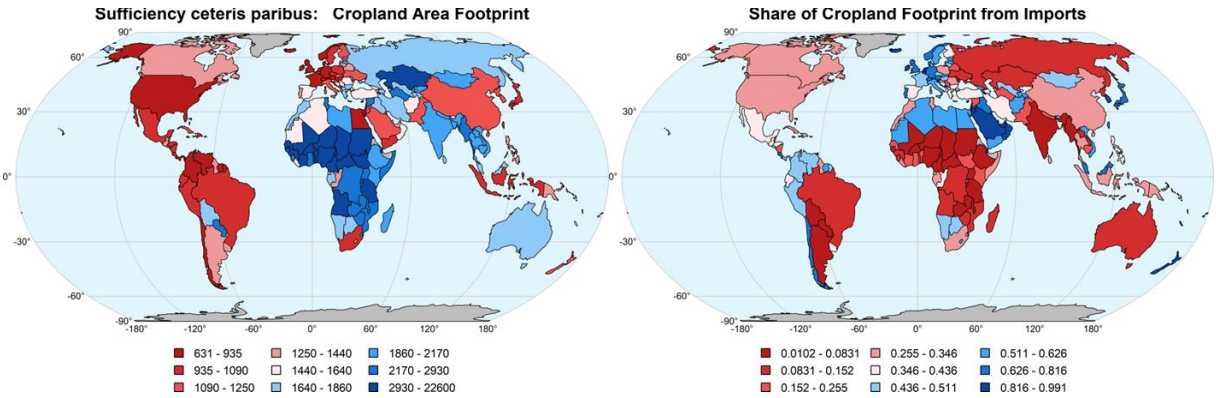


Figure 20. World maps of the Sufficiency ceteris paribus scenario (assuming everything else constant) for the downscaling of the cropland area footprint of food consumption. Values refer to a five-year average around the year 2020. Top left: cropland area footprint of food consumption in m^2 of cropland area harvested per capita and year. Top right: share of cropland footprint met by imports. Bottom left and Bottom right plots are not shown, as they highlight differences in food supply, which by definition do not exist in this scenario. Countries are grouped in quantiles, with the countries close to global median value presented in a neutral color; values with increasing intensity imply increasing divergence of the respective country from this median value. Note that the resulting classes are defined by the distribution of within the specific scenario and will differ across scenarios.

Figure 23 and 24 present results of the implementation of the **Sufficiency** scenario. For the EU and other countries that already reached this target in the ceteris paribus implementation, the results remain unchanged. Countries like Nigeria and Indonesia now by definition reach their country target. An information that this scenario can provide in addition to the previous one is level of yield increases required in the individual countries. For Indonesia this would translate to a required yield increase of 30%, for Nigeria to 124%. Both might be difficult to achieve without substantial additional intensification, considering that conditions for cropping in Nigeria might be adverse in many regions of the country and that agriculture in Indonesia is already quite area efficient on existing croplands.

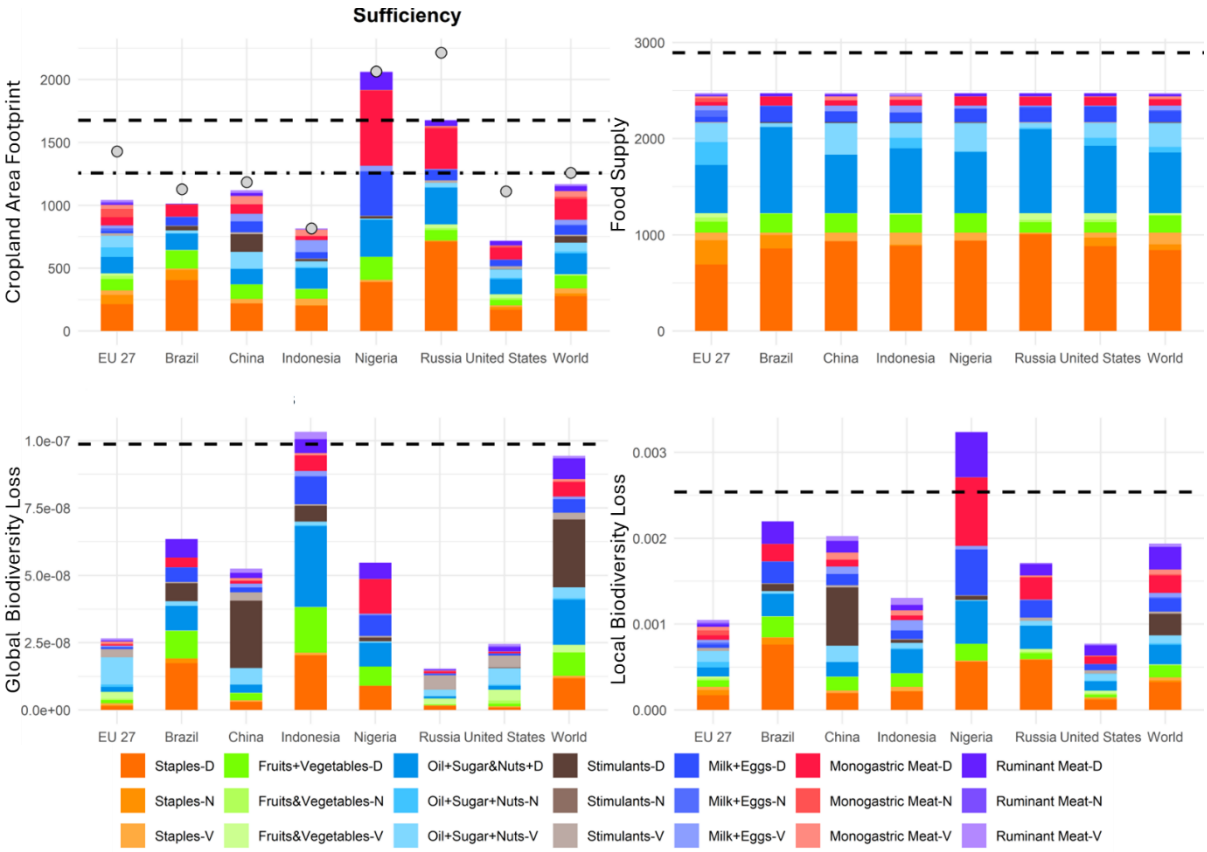


Figure 21. Results of the Sufficiency scenario (assuming yield increases to meet the global reduction target) for the downscaling of the cropland area footprint of food consumption for the EU 27, selected countries and the global average. Values refer to a five-year average around the year 2020. Top left: cropland area footprint of food consumption in m² of cropland area harvested per capita and year. Top right: food supply in kcal per capita and day. Bottom left: potential global loss of terrestrial vertebrate species in number of species per capita. Bottom right: potential local loss of terrestrial vertebrate species in number of species disappearing from a 100 km² landscape per capita. For the aggregation of crops into the presented categories, please refer to Table 9. The suffixes next to the food categories refer to: "D" domestic production. "N" imports from countries less than 2500 km away, "V" imports from countries more than 2500 km away. Dashed lines represent the overall global average in 2020 for the respective variable. For the cropland area footprint, the dot-and-dashed line represents the reduction of this global average by 25% and the gray points represent a 25% reduction of the country-specific value in 2020.

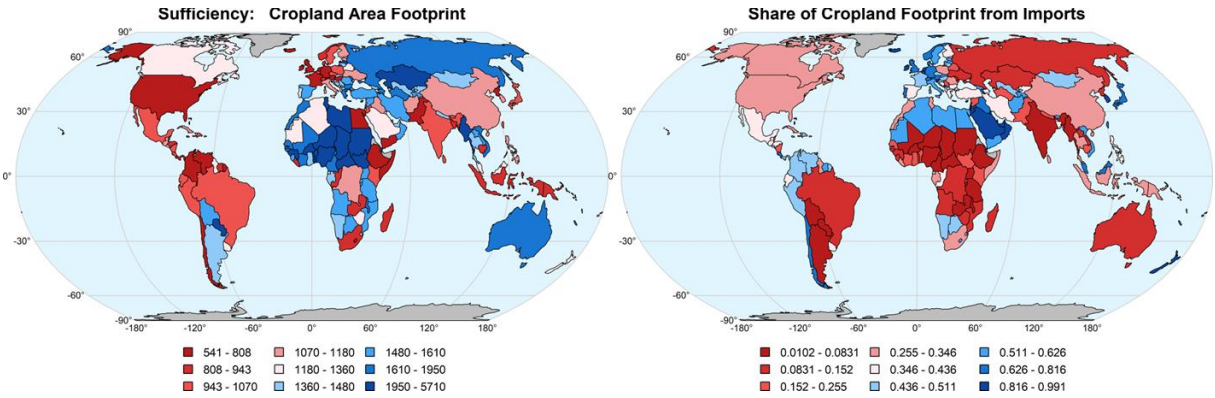


Figure 22. World maps of the Sufficiency scenario (assuming yield increases to meet the global reduction target) for the downscaling of the cropland area footprint of food consumption. Values refer to a five-year average around the year 2020. Top left: cropland area footprint of food consumption in m^2 of cropland area harvested per capita and year. Top right: share of cropland footprint met by imports. Bottom left and Bottom right plots are not shown, as they highlight differences in food supply, which by definition do not exist in this scenario. Countries are grouped in quantiles, with the countries close to global median value presented in a neutral color; values with increasing intensity imply increasing divergence of the respective country from this median value. Note that the resulting classes are defined by the distribution of within the specific scenario and will differ across scenarios.

Overall, the results for the downscaling exercise for Target 16 show that different options can contribute significantly to reduce the cropland area footprint of food consumption and associated environmental costs – but also that the potential of different strategies depends greatly on the current situation in the respective countries. They also show that global optimization holds large potential in reducing the global footprint of food consumption but that this would require close international collaboration and would have to consider (and would be potentially limited by) national self-sufficiency and food security considerations.

Table 9. Composition of food categories used for the downscaling of KMGBF Target 16.

Food category	FAOSTAT Item Code and Name
Staples	15 Wheat; 27 Rice, Paddy; 44 Barley; 56 Maize; 71 Rye; 75 Oats; 79 Millet; 83 Sorghum; 89 Buckwheat; 92 Quinoa; 94 Fonio; 97 Triticale; 101 Canary Seed; 103 Mixed Grain; 108 Cereals nes; 116 Potatoes; 122 Sweet Potatoes; 125 Cassava; 135 Yautia (Cocoyam); 136 Taro (Coco Yam); 137 Yams; 149 Roots and Tubers nes; 176 Beans, Dry; 181 Broad Beans, Dry; 187 Peas, Dry; 191 Chick-Peas; 195 Cow Peas, Dry; 197 Pigeon Peas; 201 Lentils; 203 Bambara Beans; 205 Vetches; 210 Lupins; 211 Pulses

	nes
Fruits+Vegetables	358 Cabbages; 366 Artichokes; 367 Asparagus; 372 Lettuce; 373 Spinach; 388 Tomatoes; 393 Cauliflower; 394 Pumpkins, Squash, Gourds; 397 Cucumbers and Gherkins; 399 Eggplants; 401 Chillies&Peppers, Green; 402 Onions+Shallots, Green; 403 Onions, Dry; 406 Garlic; 414 Beans, Green; 417 Peas, Green; 420 Broad Beans, Green; 423 String Beans; 426 Carrots; 430 Okra; 446 Green Corn (Maize); 449 Mushrooms; 459 Chicory Roots; 461 Carobs; 463 Vegetables Fresh nes; 486 Bananas; 489 Plantains; 490 Oranges; 495 Tang.Mand.Clement.Satsma; 497 Lemons and Limes; 507 Grapefruit and Pomelos; 512 Citrus Fruit nes; 515 Apples; 521 Pears; 523 Quinces; 526 Apricots; 530 Sour Cherries; 531 Cherries; 534 Peaches and Nectarines; 536 Plums; 541 Stone Fruit nes, Fresh; 544 Strawberries; 547 Raspberries; 549 Gooseberries; 550 Currants; 552 Blueberries; 554 Cranberries; 558 Berries nes; 560 Grapes; 567 Watermelons; 568 Cantaloupes&oth Melons; 569 Figs; 571 Mangoes; 572 Avocados; 574 Pineapples; 577 Dates; 587 Persimmons; 591 Cashewapple; 592 Kiwi Fruit; 600 Papayas; 603 Fruit Tropical Fresh nes; 619 Fruit Fresh nes
Oil+Sugar&Nuts	156 Sugar Cane; 157 Sugar Beets; 161 Sugar Crops nes; 216 Brazil Nuts; 217 Cashew Nuts; 220 Chestnuts; 221 Almonds; 222 Walnuts; 223 Pistachios; 224 Kolanuts; 225 Hazelnuts (Filberts); 226 Areca Nuts (Betel); 234 Nuts nes; 236 Soybeans; 242 Groundnuts in Shell; 249 Coconuts; 254 Oil Palm Fruit; 260 Olives; 263 Karite Nuts (Sheanuts); 265 Castor Beans; 267 Sunflower Seed; 270 Rapeseed; 275 Tung Nuts; 280 Safflower Seed; 289 Sesame Seed; 292 Mustard Seed; 296 Poppy Seed; 299 Melonseed; 311 Kapokseed in Shell; 328 Seed Cotton; 333 Linseed; 336 Hempseed; 339 Oilseeds nes; 671 Mate; 677 Hops; 687 Pepper; 689 Pimento; 692 Vanilla; 693 Cinnamon (Canella); 698 cloves; 702 nutmeg and mace and cardamons; 711 anise and badian and fennel; 720 ginger; 723 spices nes; 748 Peppermint
Stimulants	656 Coffee, Green; 661 Cocoa Beans; 667 Tea; 826 Tobacco Leaves
Milk+Eggs	882 Raw milk of cattle; 951 Raw milk of buffalo; 955 Cheese from milk of buffalo, fresh or processed; 982 Raw milk of sheep; 1020 Raw milk of goats; 1062 Hen eggs in shell, fresh; 1091 Eggs from other birds in shell, fresh, n.e.c.
Monogastric Meat	1035 Meat of pig with the bone, fresh or chilled; 1036 Edible offal of pigs, fresh, chilled or frozen; 1037 Fat of pigs; 1058 Meat of chickens, fresh or chilled; 1069 Meat of ducks, fresh or chilled; 1073 Meat of geese, fresh or chilled; 1080 Meat of turkeys, fresh or chilled; 1089 Meat of pigeons and other birds n.e.c., fresh, chilled or frozen
Ruminant Meat	867 Meat of cattle with the bone, fresh or chilled; 868 Edible offal of cattle, fresh, chilled or frozen; 869 Cattle fat, unrendered; 947 Meat of buffalo, fresh or chilled; 948 Edible offal of buffalo, fresh, chilled or frozen; 949 Buffalo fat,

	unrendered; 977 Meat of sheep, fresh or chilled; 978 Edible offal of sheep, fresh, chilled or frozen; 979 Sheep fat, unrendered; 1017 Meat of goat, fresh or chilled; 1018 Edible offal of goat, fresh, chilled or frozen; 1019 Goat fat, unrendered

§6 Insights when looking at downscaling results across targets

Comparing the results of such a downscaling exercise across targets can highlight how the implementation of the same justice principles and value perspectives across different targets could lead to synergies or trade-offs on the way to reaching these targets simultaneously. For example, one scenario we implemented for targets 3, 7 and 16 is an environmental capacity scenario, which combines a capacity perspective on justice with a nature for nature value perspective. When implementing this scenario for the three selected targets, biodiversity considerations always played a crucial role. However, for target 3 and target 16 the focus was on global biodiversity value of lands, while the focus for target 7 were impacts of nitrogen surplus on local ecosystems (as nitrogen pollution is in many contexts a local or regional issue, Schulte-Uebbing et al. 2022). Consequently, both the results for target 3 and target 16 would point towards maintained agricultural production within the EU while limiting the expansion of PAs and OECMs. The implementation for target 7 of the environmental capacity scenario would imply significant reductions of the nitrogen surplus within the EU. This would point to a discussion on how agriculture could be extensified within the EU, how food consumption could be changed without increasing pressures on areas outside the EU, which would see increased protection and reduction in cropland use in these scenarios. This is one example for such potential synergies and trade-offs between targets, based on our data work. Ideally such results would be fed into further discussions with stakeholders which could then lead to refined scenario delineation and quantifications.

§7 Outlook and next steps

Accounting for diverse value perspectives and perceptions of justice will be important levers in tackling the biodiversity crisis (IPBES 2022, 2024). Results of such

downscaling, as applied here, can help understand quantitative implications of different value perspectives and justice perceptions on sharing the efforts towards internationally agreed biodiversity targets and may serve as mirror to planned and implemented actions towards such targets. Integrated assessment and biodiversity models can then be applied to understand potential interactions between goals and targets for biodiversity and other sustainability dimensions given different scenarios how efforts towards these targets may be shared.

This approach of downscaling biodiversity targets, while accounting for diverse perspectives of values and justice, can be applied to further targets from the KMGBF and other international agreements, e.g., the EU Biodiversity Strategy (European Commission 2020). Candidate targets are particularly those, that have quantitative elements or can be interpreted in a quantitative way, e.g., KMGBF target 2, stating to restore 30% of all degraded ecosystems, or target 11, aiming to restore, maintain and enhance nature's contribution to people (CBD 2022a).

The downscaling work presented here and in D1.3 will be further refined, and results will be published in a scientific journal alongside the updated data and the scripts utilised to produce them. Some refinements we plan are: For target 3, we plan to implement a version of the efficiency scenario that accounts for existing protected areas and OECMs and test other proxies of cost. For target 7, we aim at refining the scenarios, by implementing a maximum ratio of nitrogen surplus per ha cropland and by accounting for currently soil mining countries in a way that avoids assigning them negative nitrogen surplus budgets in scenarios such as the grandfathering scenario.

C - APPENDIXES

1. Expert feedback on draft pathways

We disseminated the draft pathways in D1.1 for expert feedback on specific and general aspects of the paths through professional food-and-biomass policy and research networks. This section details the findings of this expert feedback process while reserving the anonymity of the experts involved. We received detailed feedback from 3 experts (two from the science-policy interface and global biodiversity scenarios, and one expert in model and scenario applications for agriculture in a European context), in through emails and online meetings.

Experts commented on the relevance of the framework and planed applications for supporting KMGBF implementation and match to the scope of the second global IPBES report and pointed to aspects that were underdeveloped and/or unclear in the draft pathways, as well as perceived barriers and enablers of each pathways.

We used this feedback to direct our efforts in revising elements already developed in the draft pathways, expanding the narratives in additional directions (e.g., interventions and feasibility) and providing a long text description of each pathway. Table 10 provides a summary of the main comments received by type of expert, and how they were addressed in updating the pathways.

Table 10. Summary of received comments received from scenario and model experts, and how they were addressed.

Expertise	Comment	How it has been addressed
Scenarios & models for the agricultural sector in the EU (EUR-AGRI-SSPs, Austria)	The pathways are not detailed enough on the biodiversity, intervention and feasibility dimension, and material presented in D1.1 could be mobilized to develop this aspect	We produced a detailed narrative for each pathway, in which we provided try to expand the details provided on additional information on biodiversity (through specifying whether instrumental, relational and intrinsic valuation of nature dominates, and implications for landscapes), interventions (with a detail along specific sectors), and feasibility considerations related to anticipated barriers and enablers.
	The time frame (2030 and 2050) is not clear, I would decide for one period and make this explicit.	We agree this was not enough clarified upfront, and we added a general scope section at the beginning of the updated pathway description. We however decided to keep the two horizons of 2030 and 2050, to include both short-term and policy-relevant horizon (most useful to discuss upcoming towards global goals) and the longer-term to which social and environmental goals often refer to.
	On pathway title two of them refer to global, while one does not? I would make the global focus clear in all scenarios upfront.	All pathways are global in their scope, but the global vs local wording of the titles referred to preferred scale for governance. In the updated pathway description we clarified the global scope of the pathways in the a new general scope section.
	Narrative 1: some fine-tuning might be needed for clarity, e.g., *green* innovations, *resource-use* efficiency etc.	Agreed
	Narrative 2: to me, this reads as if Ostrom's Design principles would fit in here very well	x
	Narrative 3: I think that consumer awareness is not enough here to make this scenario 'work'. I am not yet convinced about the 'flow' of the narrative – e.g., how are people convinced to behave in the expected way? How do the global norms develop? It reads like: if institutions are introduced and consumers aware, sustainable development could be achieved – I don't think this is enough.	In the updated description, we tried to clarify what assumptions this narrative entails (e.g., all types of actors agree to an unprecedented level of delegation of authority to expert-led, global institutions, with concessions to powerful actors to make it happen – such as rejecting historical responsibility as a relevant principle to distribute efforts) and what types of barriers might limit the occurrence of such a future.
	p97 refers to SSP2, but I would argue that any normative scenario with a focus on sustainable development is	SSPs in general embed many assumptions that might not easily be compatible with each of the pathways presented

	within SSP1?	here. For example, SSP1 would not be compatible with the focus on extensive land use in the local stewardship pathway, but might be less ambitious in terms of dietary shifts. In addition, while SSP1 being the most sustainability-oriented, it also assumes lower demographic dynamics than all other SSPs, which may not necessarily be justified in all RAINFOREST pathways. When it comes to population, SSP1 is lower than any other SSP: we believe that based on narratives there is no strong rationale for aligning RAINFOREST pathways on SSP1, and a more central assumption (SSP2) might be more adequate. While this is debatable, we can test the influence of such a choice via a sensitivity analysis.
Biodiversity future scenarios, Global science-policy interface	The Global green innovation scenario might be perceived as the closest to the BAU for business and conservatives, and one barrier to achieving positive futures for Nature and People could be that insufficient motivation from private actors / incentives from states to really achieve positive futures	This is in line with our understanding of potential barriers to that scenario (in addition to possibly unrealistic level of technological innovation), and in the updated pathway description (D1.2) we explicitly mention it (together with others) in a barriers and enablers descriptor (developed for all scenarios)
	The global stewardship pathway might be perceived as technocratically exacerbated version of the status-quo. It might have some chances for success due an explicit layout of the roadmap, but could also see many of the targets unmet.	This is in line with our understanding of potential barriers to that scenario (which would need to assume an empowerment of state actors to ensure implementation), and in the updated pathway description (D1.2) we explicitly mention it in a barriers and enablers descriptor (developed for all scenarios)
	The local stewardship would have very limited chances to happen as this represents the utopian vision of insufficiently powerful actors.	This is in line with our understanding of potential barriers to that scenario (which would need to assume a strong shift in values), and in the updated pathway description (D1.2) we explicitly mention it in a barriers and enablers descriptor (developed for all scenarios)
	A blend of the global and local stewardship might work best as a feasible pathway, as it combines the global vision and the local prioritization.	We believe that this might however entail difficulty compatible sets of values, in particular on freedom at the individual level, and intrinsic value of nature. We are currently considering how to build another pathway that could build on a more coherent set of values.
	I would have liked to see more coverage of GBF and perhaps Sustainable Development targets	We for now covered this aspect in one row of table could consider expand a bit the content of Table 9 (Outcome targets / Human

		wellbeing targets), and in short description. This is not within the highest priorities for narrative improvement, but hope that the modeling activity can provide more concrete illustration, for example around human health, food security and food consumption inequality.
	It's very EU-triomphant – and perhaps a bit galling in that regard – for the pathways to have broader reach beyond the EU, perhaps it would be relevant to investigate how Europe could consider relevant to reduce its negative footprint across continents now, and intergenerationally, as part of justice dimensions	This to some extent the vision of EU to lead the way on the sustainability transition, but some pathways also explicitly assume justice-based considerations to reduce consumption and negative external material and environmental footprints – we will try to more systematically explicit this dimension for each pathway.
x	Based on the scoping report of the second global IPBES assessment, the pathways seem to be well targeted in terms of scope i(transformative change in KMGBF implementation, justice, deeper dive into multiple perspectives and KMGBF implementation interventions and impacts)	Agreed, we'll try to take the scoping report into consideration to make the pathways even more relevant
	The question of burden sharing, and whether targets need to be translated 1 to 1 from global to country level (e.g., each country has to achieve 30% PA) or can be distributed differently, are one of the big elephants in the room at CBD discussions, with limited willingness to have open discussions about it. This means that the work done with the pathways might not be welcome by all parties, but could actually facilitate implementation if not too naïve.	We will try to reflect different views in the pathway design and organize some level of iteration between the target downscaling and the pathway narrative finalization to increase the potential for positive impacts on implementation discussions.
	I would not recommend to make more than 3 to 5 contrasted pathways, as it becomes more difficult to digest. When it comes to the modeling, this might make it difficult to attribute the differences in outcomes across pathways to specific pathway assumptions (as many vary between pathways) but this can be dealt with by other methods (e.g., sensitivity analysis)	We considered the addition of one or two additional pathways (a pathway including scoring low on the scale of governance and high on the role of markets; a compromise pathway trying to balance elements of other pathways for higher feasibility), and decided xyz

2. Preliminary parameterization of the pathways in GLOBIOM

The following tables document a preliminary parameterization of the three pathways in the GLOBIOM land use model for two value chain segments, sustainable consumption and agricultural production. This parameterization aims to reflect the narratives of each pathway in terms of consumer preferences, dietary shifts, food access inequality, farming practices, and resource efficiency. References used for the parametrization are documented, along with adjustments made to better reflect the narratives. This will serve as input to the modelling of the pathways in GLOBIOM. The scenario quantification is on-going, and the parametrization of these areas might be revised, while additional areas (such as Forestry, Trade and intermediate value chain or Protected areas and restoration) will be parameterized.

Table 11. Preliminary parameterization of the pathways in GLOBIOM - Sustainable consumption

Sustainable Consumption				
Model input parameters	**International Market Innovation**	**Global Sustainability Orchestration**	**Local Commons Stewardship**	**Impact in the model and references**
Exogenous dietary preferences	SSP2 dietary trends with widespread adoption of Novel Plant-Based Alternatives (NPBA, 50% substitution in 2050 compared to 2020 levels);	Partial transition towards Eat-Lancet diet. Moderate NPBA adoption (25% substitution in 2050 compared to 2020 levels)	Full adoption of Eat-Lancet diet, with a preference for local product; no NPBA	In the model, these affect the per capita level of demand prior to price-driven endogenous adjustments. SSP2 trends in dietary preferences reflect historical trends and are detailed in Valin et al (2014). Adoption of NPBA based on Kozicka et al (2023), the different levels of substitution are adjusted to match the narratives. Eat-Lancet diet refers to planetary health dietary guidelines focusing on human health and food system environmental sustainability (Willet et al 2019), we here use the second version of the EAT-Lancet diets.
Food consumption tax	-	Tax on overconsumption of unhealthy food (e.g., red meat, sugar) exceeding	-	In the model, these affect the effective per capita levels of demand (together with endogenous

		recommended intake levels		market dynamic driven price adjustments) by increasing the price of specific food items, based on their nutritional content and dietary preferences. The design of the tax on overconsumption of unhealthy food is based on Latka (2020).
Maximum consumption levels	No limits; follows baseline assumptions	Overconsumption reduced by 50%	Overconsumption fully eliminated; intake aligned with dietary recommendations	In the model, the endogenous food demand of specific products in each region is modeled for an average consumer, whose consumption preferences reflect a broader distribution of consumption patterns. Reducing the upper bound of consumption levels leads to lower average consumption values. In addition, following Hasegawa et al. (2020), implications for the inequality of food access and distribution (measured through a coefficient of variation) can be translated into changes in the number of people at risk of undernourishment. In the model, reductions in food waste and losses reduce the required production needed to satisfy demand. The amount of waste and loss is derived from FAOSTAT data and the parameterization of food loss & waste reduction follows SSP1 trends from Popp et al (2017) as minimum improvements, with higher reduction for selected components in most scenarios. The food consumption patterns are translated into changes in health
Inequality in access and distribution of food	Only partial reduction in inequality: Coefficient of Variation (CV) remains relatively high	Significant reduction of CV through redistribution and food safety networks	Maximum reduction in CV through targeted interventions and inclusive systems	
Food waste	Moderate reduction (by 30%-40% by 2050)	High reduction due to legislation (by 70-80% by 2050)	High reduction driven by awareness (by 70-80% by 2050)	
Food Losses	High reduction due to the technological improvements along the value chain (by 70%-80% by 2050)	Medium reduction due to legislation and subsidies to technologies (cold storage etc) (by 50%)	High reduction due to shortened value chain (by 70-80% by 2050)	
Health impacts	(expected) Reduction of diet-related health risks by ~50%	(expected) Reduction of diet-related health risks by ~70%	(expected) Almost full elimination of diet-related health risks	

Hunger impacts	(expected) Undernourishment remains in some regions of the world, obesity levels similar to baseline	(expected) Undernourishment eliminated; obesity significantly reduced	(expected) Both undernourishment and obesity fully eliminated	impacts from food consumption, while the food consumption levels, price levels and food access and distribution inequality are translated into prevalence of undernourishment. Indicators developed in RAINFOREST/WP2

Table 12. Preliminary parameterization of the pathways in GLOBIOM – Agriculture production

Agriculture production				
Model input parameters	**International Market Innovation**	**Global Sustainability Orchestration**	**Local Commons Stewardship**	**Impact in the model and references**
Agroecological intensification technologies	Predominance of adoption of precision farming practices, reaching 60% of agriculture land in 2050; slow growth of organic agriculture, reaching 10% in 2050	Balanced mix of organic agriculture, precision farming adoptions, reaching respectively 40% and 30% of agricultural land globally in 2050.	Widespread local agroecological practices including agroforestry, and organic farming	In the model, these affect two different types of parameters. First, this affects the share of production activities under different technologies, that differ from conventional agriculture in specific ways (e.g., lower yield and lower fertilization organic agriculture, higher yield and lower fertilization for precision farming). Second, this affects additional trends in yields and input (water, nutrients, other chemicals) assumed to occur for all conventional and alternative production systems alike, to reflect long-term trends in agriculture research and development. Agroecological intensification is Adjusted from FAO (2018), Frank et al (2024), and considering F2F targets for EU. Yield trends and water use efficiency are adjusted from IMAGE estimations of the SHAPE pathways in Weindl et al (2024). Nutrient use efficiency trends are based on Weindl et al
Yields	Highest increases: ~20% in OECD, 40-130% in non-OECD by 2050, enabled by technology improvements	Stable OECD yields until 2050, then ~20% decline; moderate non-OECD increases (20–115%)	Growth focused in low-yield systems; declining/stable yields in OECD; lowest gains in non-OECD (15–95%)	
Irrigation efficiency	High improvement: +30% in OECD, +40-140% in non-OECD by 2050	Moderate gains in non-OECD (20–120%); increase then decline in OECD post-2030	Stable or declining efficiency, especially in OECD (up to -20%)	
Nutrients improvements - Use efficiency	Convergence towards high NUE: minimal gains in OECD & EU and regions with high NUE and high improvement in regions with lower NUE. Achieved through uptake of precision farming and complemented with general NUE Improvements within conventional croplands	Convergence towards high NUE: minimal improvement in OECD & EU and regions with high NUE and high improvement in regions with lower NUE. Achieved through a mix of precision and organic farming and complemented with general NUE improvements within conventional croplands	Convergence towards medium NUE: most improvement in lower NUE regions, while NUE trends might remain stable or moderately increase in high NUE regions. Achieved through both uptake of organic farming and general NUE improvements within conventional croplands.	

				(2024) and Kanter et al (2020), following high policy scenario for IMI and GSO, and Medium for LCS.
Livestock systems	Mixed crop-livestock systems, with higher efficiency gains, thanks to technological advances	Mix of crop-livestock systems and grass-based systems with moderate improvements in productivity	Primarily grass-based systems, with low inputs, and moderate improvements in productivity	In the model, this directly affects the share extensive (primarily grass-based) vs mixed (grains and grass) livestock production systems for ruminants (which indirectly affects several aspects such as feed requirements, feed conversion efficiency, manure production and management, GHG emissions), as well as exogenous trends in feed conversion efficiencies for various livestock species and livestock production systems. Additional information on the parameterization of livestock systems can be found in Havlik et al (2014).
Nutrients improvements - Manure recycling	90% recycling by 2050 in OECD; 50% increase in recycling in non-OECD by 2050	90% recycling by 2030 in OECD; 50% increase in recycling in non-OECD by 2030	90% recycling by 2050 in OECD; 50% increase in recycling in non-OECD by 2050	In the model, this affects how much manure is recovered from confinements, and available for application on arable land. Based on Kanter et al (2020), following High policy ambition scenario for GSO, Middle policy ambition for the others

3. Sketch View of a Fourth Pathway

§1 Rationale

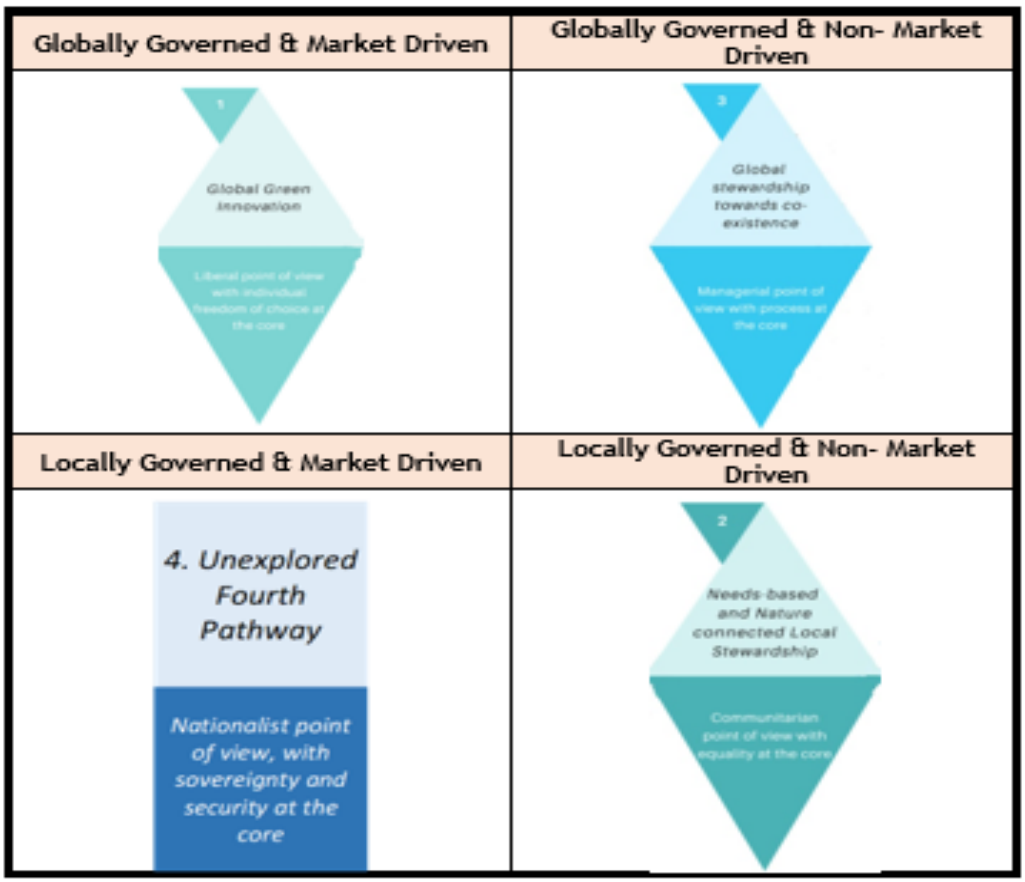
In D1.1 Section 5.4 the potential for the RAINFOREST project to develop a fourth pathway was mooted, with the aim of developing a "balanced" view drawing together compatible elements of each of the D1.1 pathways. This avenue was not pursued. However, in the course of revising the D1.1 pathways, the working group had substantial discussions over the prospect of a fourth pathway exploring additional perspectives on justice which had potentially been overlooked.

Following the feedback from the WCSG workshop, it was suggested that the Global Green Innovation pathway could be adapted to reflect political trends away from the Washington Consensus led trend of market globalisation, towards an renewed focus on nationalism, protectionism, and securitisation. While this suggestion was based upon a mistaken belief that Global Green Innovation reflected a "business as usual" pathway that attempted to project current political, social, and economic trends, rather than a positive transformative vision itself, we noted that it was possible that the D1.1 pathway set had overlooked a particular perspective on justice; which could be fruitful to model.

The relationship of such a 4th pathway – tentatively named "National Sovereign Guardianship" – to the pre-existing pathways could be illustrated by employing a chart with a set of two axes depicting the scale on which governance operates (local to global) and the relative importance of markets as a distributive mechanism (high important – low importance). While the use of "spatial" models to examine the "dimensions" is a relatively commonplace tool in "pop" political analysis, within the social and political sciences their usage has been methodologically critiqued (Benoit & Laver, 2012). Nonetheless, a similar means of categorising scenarios was employed in the Millenium Assessment Scenarios (Millenium Ecosystem Assessment. 2005. P.19.). Therefore, as a simple heuristic categorisation tool, it can give us way of conceptualising how the D1.1 pathways fit together – and we found the existing three D1.1 pathways could be intuitively fit to such a chart.

Global Green Innovation features gives a prominent role to market actors stimulating green economic growth through an ever-greater globalisation of market forces, allowing markets to rationalise sustainable production. Global Stewardship features an expansion of global governance and a centralisation of political authority into these spaces, allowing global governing institutions to play an increasing role in organising production through command-and-control policies, in order to coordinate production, direct it towards biodiversity positive modes, and to manage redistributive measures to meet a prioritarian focus on poverty elimination. Needs Based and Nature Connected Local Stewardship, as the name suggests, envisions a devolution of political authority into the hands of "local" governance. The explicit focus on an egalitarian needs-based economy implies that within these local communities there are distributive mechanisms which can redistribute goods to ensure equality across some meaningful metric (e.g., capacities). The fact that our existing scenario drafts could be fit to such a axis demonstrated its functionality as a means for classifying and understanding the relationships between the D1.1 pathways. Moreover it was employed as a methodological tool for soliciting feedback on the pathways in Workshop 3.

Table 13. Mapping of D1.1 Pathways to an Axis "Market-Non Market / Global- Local" and highlighting potential of a 4th Pathway



A review of comparable scenario projects identified existing scenario pathways examining global environmental change which could form the basis for such a 4th pathway. It was found that while environmental scenarios had been created previous with a focus on regionalisation/securitisation/interstate competition/ and market driven dynamics, these scenarios were frequently given an expressly negative sentiment.

Table 14. Existing Environmental Scenarios with Regionalisation/Securitisation/Competition/Market-Based Dynamics

Project	Scenario	Scope	Sentiment
Millenium Assessment Scenarios	'Order from Strength'	Global	Negative (unclear)
Shared Socioeconomic Pathways	SSP3 – Regional Rivalry	Global	Negative
Bringing Nature Futures to Life	Most like NC-NS 'Innovative Commons'?	Global	Positive
Sustainable Development Pathways	Partially in 'Local Solutions' and 'Green and Social Market Transition'	Global	Neutral
IPBES Scenario Archetypes for Europe & Central Asia	'Regional Competition'	EU (and central Asia)	Negative/Neutral (aggregate of existing scenarios)
Perspectives on the future of nature in Europe – scenarios and storylines	'Strengthening Cultural Identity'	EU	Positive
Reconciling safe planetary targets and planetary justice	Similar use of 4-point axis, quadrant q3.	/	/

It was the professional judgement of the Working Group responsible for the RAINFOREST Pathways that, as the RAINFOREST Pathways aim to depict *positive* futures which *plausibly* make progress on halting biodiversity loss, this scenario failed to achieve those aims and therefore would not be included in the final scenario set. This was because it was believed that preventing a breakdown in international cooperation would be needed to meet biodiversity objectives, including the KMGBF vision of a "World Living in Harmony with Nature". Similar rationales have been applied to comparable environmental scenarios that have also been used to explore a world characterised by inter-state competition and regionalisation: including

"Order Through Strength" in the Millenium Assessment Scenarios, and "Regional Rivalry" in the Shared Socio-Economic Pathways. Nonetheless, given the interest expressed by our stakeholder group, and the general lack of global scale scenarios currently exploring these dynamics it is our hope that future research could further contribute to understanding this pathway.

This Appendix lays out a sketch view of a fourth RAINFOREST pathway. The rationale for developing a fourth pathway is given in detail in D1.2 "Revision of the Pathway Drafts". It was the professional judgement of the Working Group responsible for the development of VITAL-PATHS-FOOD that as the VITAL-PATHS aim to depict *positive* futures which *plausibly* make progress on halting biodiversity loss, this scenario failed to achieve those aims and therefore would not be included in the final scenario set. This was because it was believed that preventing a breakdown in international cooperation would be needed to meet biodiversity objectives, including the KMGBF vision of a "World Living in Harmony with Nature". Similar rationales have been applied to comparable environmental scenarios that have also been used to explore a world characterised by inter-state competition and regionalisation: including "Order Through Strength" in the Millenium Assessment Scenarios, and "Regional Rivalry" in the Shared Socio-Economic Pathways.

Nonetheless a narrative focussed redux of this pathway is included as an appendix here. Our reasoning is threefold. Firstly, because the objectives of the RAINFOREST project was to explore the impact of incorporating justice and values of nature into biodiversity scenarios a systematic, value-explicit way, while remaining non-normative. The purpose was to present each vision of justice in a non-evaluative, standpoint independent manner, to explore the impact of competing visions of justice on the way in which the food and biomass system would be organised. We believe that from this research standpoint it is improper for us to stake a claim on whether this is a normatively desirable vision. Yet it is clearly evidencable that this is a distinctive account of justice that animates and motivates real world actors today. Secondly, the RAINFOREST project seeks to design its pathways through an iterative process incorporating feedback received from stakeholders. In our feedback sessions, expert stakeholders advised us that their assessment was that ongoing

political developments appeared to show a world progressing along a pathway like the one envisioned here – characterised by a breakdown in globalisation and a refocussing on securitisation. Exploring these trends and whether they could potentially offer a pathway to halting biodiversity loss is therefore a response to that feedback. Finally, if indeed political trends do appear to be progressing in the direction of this pathway, it is valuable to explore what opportunities there may be to advance a sustainability agenda within these political conditions. Scenarios research for biodiversity is a comparably recent field; and while it has been argued that scenarios are needed to envisage positive futures for biodiversity, they may also play a role in exploring challenging circumstances too. We hope to open up discussion and prompt reflection on strategies to advocate for nature within a changing geopolitical landscape.

§2 National Sovereign Guardianship

In this world the values of personal responsibility, national self-determination, and oikophillia (love of home) (Scruton, 2013) become prevalent. Nation-states remain as the key actors globally and take on a role of guardians of both their natural and cultural heritages. A key animating factor in this world is renewed global focus on national security. Nation states see their top priority as securing the wellbeing of their national communities. Recognizing the risk that a collapse or loss of nature's contributions to people poses to national wellbeing, in this pathway halting biodiversity loss becomes a highly securitized discourse (Lieven, 2020). Framed in such a way, states become enabled to take extraordinary measures to protect and secure their ecosystem services – viewing it as part of their national defence strategies essential to long term survival.

Refocusing on national security leads nation-states to view themselves as the only actors capable of guaranteeing the wellbeing of their citizens. There is a broad scepticism of strategies that rely on goodwill or cooperation with other states. The view of justice might be described as liberal nationalism, people view themselves as having special obligations to their community in-groups, particularly their national communities. In terms of global distributive justice, they view themselves

as having predominately negative obligations to others – duties to ensure they do not violate the rights or sovereign independence of other nations, but very few positive obligations to render assistance or improve the lives of others; perhaps beyond a low-threshold sufficientarian commitment to ensuring that no one lives in extreme poverty.

This skepticism towards globalization leads to a rejection of both international cooperation, as well as the prevailing post- Washington Consensus free-trade world economic system. In this pathway multinational and global governance institutions become less prominent, and are replaced with looser networks of trans-national governance, which enable states to retain sovereign control over decision making and the utilization of their territories. States have a variety of motivations for wanting a breakdown of this order, and seeing it as compatible with halting biodiversity loss.

In the Global North, states are concerned that international free-trade with long, complex, "just-in-time" supply chains has made them vulnerable to ecological breakdown; and reliant on environmental policies in foreign nations over which they have little ability to influence. By imposing protectionist economic measures, including targeted tariffs on foreign goods, but also agro-industrial stimulus packages, they aim to stimulate a reshoring of both agricultural and industrial production. Food security and resilient short supply chains are identified as the best means of ensuring the quality and sustainability of produce is ensured, and nations aim for self-reliance as far as possible, through the application of innovative techniques and locally developed green technologies. In the agriculture and forestry sectors the strategy is one of sustainable intensification. States aim to reduce reliance as far as possible on imports and focus on increasing production within their territories. While full self-reliance will very rarely if ever be possible, shortfalls are made up for by near-shoring through bilateral trading agreements with trusted partners. The securitization framing of agriculture and ecological protection allows states in the Global North to leverage and reallocate funds from other parts of their national budgets. In response to fears of global instability and conflict, states increasingly abandon neoliberal fiscal discipline for military-

Keynesianism, leveraging their ability to borrow at low rates to stimulate defence production. In a pathway where food security and halting ecological breakdown are intrinsically linked to civil defence, this influx of new capital is utilized to subsidize new green technologies to enable sustainable intensification, and investments in nature to secure ecosystem service provision. The market, private companies and the innovation that it offers is still seen as central to this pathway, even though global trade is restricted and governments attempt to steer market-forces in strategic directions. Higher prices for goods creates a pressure which lowers overall global north consumption; which promotes a revolution in sustainability and circularity of resource use, and stimulates shifts towards traditional and culturally significant diets – which nationalist states are happy to promote.

The breakdown in the Washington Consensus is valued for other reasons by nations in the Global South. Long critical of the free-trade measures imposed on them by the World Bank, IMF structural readjustments, and ODA conditionality, states in the global south see the breakdown of globalization as an opportunity to pursue alternative development strategies (Chang, 2002). Resource rich countries in the global south are able to achieve higher prices for their goods and to stimulate north-south capital flows, through coordinated actions such as forming producer cartels. Export-led development strategies remain viable, especially in producing key goods which cannot be grown outside of the tropics. The focus on on-shoring production in the global north decreases the land-pressure on the result of the world, allowing them to raise their own consumption, as well as devote more land to conservation owing to the lessened pressure for land. As there is comparably less demand for agricultural products for export, Global South agriculturalists can also devote more space to culturally significant low impact growing methods, which provide food types. Global South states are able to exert full autonomy over how their resources are used, exert their right to devote as much of their territory to protected areas as they feel necessary, knowing best how they want to prioritize wilderness areas with opportunities for national development and resist the authority of internationalist institutions to impose burdens on them. Agricultural intensification and extensification strategies vary from nation to nation, depending on the particularity of their circumstances, the availability of key resources locally,

and the chosen development strategy of that nation. In some regions there are localized decreases in biodiversity where resource extraction is on-shored or agricultural production is intensified, however the net-effect overall is positive as states globally act to protect their own interests n avoiding ecological breakdown.

In all states, the return to liberal nationalist, communitarian values leads to a renaissance of cultural valuations of nature. A country's biological heritage is a valued part of cultural traditions and a source of patriotic national pride. Intergenerational justice is promoted through a strong respect for property rights and inheritance. The cultural and natural heritage of every country is seen as something to be passed down, as little changed as possible, to the next generation. The pressure to set land aside for nature, and for market actors to act sustainably in both the Global North and Global South is robust bottom-up pressure from motivated civil society groups, who feel a strong sense of national pride in the countries' national environments. Inspired by their love of their homelands, and a strongly felt connection to their biogeography, citizens can leverage their governments to discipline bad-actors into adopting sustainable business practices. Likewise, governments are also concerned with ensuring that their viability as a state and their national self-reliance, is not compromised by ecological breakdown, and thus create strict regulatory regimes for their national markets under the auspices of protecting national security, and guarding resource uses wisely.

4. VITAL-PATHS-FOOD Pathway Assumptions Comparison Tables

Table 15. Forestry Assumptions

VITAL-PATHS-FOOD: Forestry Assumptions			
	International Market Innovation	**Global Sustainability Orchestration**	**Local Commons Stewardship**
Restoration Preference	On Degraded Lands	Managed to Wild transitions	Within Managed
Forest Typology (FAO, 2009) and Naturalness (Barredo et al, 2024)	High-productive fast-growing plantations and protective plantations to secure ES in strategic locations, allowing space for naturally regenerating forests elsewhere. Fast growing plantations for HWP offers a faster means of removing carbon than increasing forest carbon in the short term. Permissive attitude to non-natives where these secure ES and are profitable investments. Naturalness not an objective per se where managed/combined objective forestry can meet biodiversity standards.	Productive and protective plantations with a focus on meeting biodiversity objectives. Naturalness and the protection of near virgin and old growth forests is a priority. Expanding connected areas of native forests means expanding partly natural planted forests, and leaving some plantations to revert to unmanaged secondary forests. Preference for plantation-like natural forests in productive spaces where this does not substantially compromise space saving.	Preference for native combined-objective/multi-functional forestry that can support biodiversity, ecosystems services and provide cultural services. Intensively managed plantations can be restored to partly natural medium or low/close- to-nature forestry as demand/consumption lowers. Exotic species thinned out to support culturally significant species and ecotypes.
Distributive mechanism	Market led through PES schemes, pricing of environmental externalities and biodiversity & carbon offsetting to identify optimum price locations for forests minimizing agricultural conflict.	Centrally planned to ensure long-term strategic forestry ends as well as biodiversity benefits through ecosystem connectivity.	Community autonomy in placement of forest according to locally specific and culturally derived goals. Significant role for non-market factors in deciding forest location.
Landscape	Determined by calculations of marginal utility with some strategic planning through PES to locate forests where they can provide landscape scale ecosystem services such as flood control and water filtration. The aim is to find sites with low value for intensive agriculture to minimize conflicts. Pressure to convert non-agricultural land to forest is tempered by some state imposed protections for non-forest ecosystems.	Focus on ecosystem connectivity to deliver optimum conservation outcomes. Connectivity between conservation and intensive productive forestry, aiming to minimize space conflict with agriculture.	Short supply chains and local community attachment/use creates an extensive patchwork landscape of forests interspersed with farms. Forests support pollination needs and also provision local economies through silviculture and low intensity forestry.
Global Distribution	Cost effectiveness – wherever the market finds space for high intensity production. Typically, new forestry is sited on cheap lands in the global south, which roundwood production in the	Conservation priority - Restored quasi natural forests where conservation needs demand it and focus on strong preservation of existing natural forests. Focus on connectivity and strategic landscape planning, plus high	Short supply lines lead to an extensive distribution of forests globally, with a low focus on connectivity and creating wild-forests, except where

	tropics and in new forests the very high latitudes. Global energy use is high, so carbon forestry is prominent, and demand is high for carbon forestry. Conservation forestry on marginal lands saving space for productive forests.	intensity plantations to meet biomass needs. Species preservation is a key aim and highly protected forests are sited to prevent vulnerable species extinction	high protection is essential for ensuring ecosystem service provision or to preserve keystone species. People live within and amongst forests, and a dispersion of quasi-natural forests supports pollination and water management service provision.
EU	Modest expansion of forests, both conservation and productive, largely on marginal or abandoned agricultural land or at high latitudes. There is a strong distinction between intensively managed plantations and natural protected forests. PES leads to some strategic placements of forests to regulate water catchments and provide location specific ecosystem services.	Less focus on cost effectiveness so proportionally more commercial forests in high latitudes saving space for development in the global south. Strict protection and closer to nature forestry elsewhere in mainland Europe. EU supports and finances forest conservation in the tropics, offsetting opportunity costs to development.	Native broadleaf woodlands and pines, with low intensity production and multifunctional forestry throughout mainland Europe. Extensive forests in the high latitudes with vibrant and populous communities moving to the region to work rewarding forestry jobs. Reduced demand for tropical species and packaging.
Product types and management practices	Competitive market leads to fast growing plantations for HWP and low prices, supporting high consumption and short-term need for carbon storage. Ecological costs of these forests brought down by precision techniques reducing fertilizer demand.	Lower overall supply than IMI but a focus on long term sustainable forests, strategic planning, and a controlled economy setting prices and focused on ensuring supply for strategic purposes, e.g., construction.	High-quality value-added products, and regional variation over uses and product types. High prices keep demand low. Low intensity logging in extensive semi natural forests. Silvacultural production reduces agricultural conflict, plus high visitation and amenity values.

Table 16. Agriculture Assumptions

VITAL-PATHS-FOOD: Agriculture Assumptions & KMGBF Target 2 & 7			
	International Market Innovation	**Global Sustainability Orchestration**	**Local Commons Stewardship**
Restoration Type 1. Conversion Taking areas out of production 2. Pollution reduction on managed land	Restoration: Type 1 and Type 2. Decreasing on-managed land biodiversity damage by adopting precision farming techniques which reduce need for pesticides. Raising yields to allow some areas to be removed from production.	Restoration type 1 and 2. Focus on connectivity of unmanaged landscapes and reducing extinction risk by saving space for strictly protected areas through efficiency gains in production.	Restoration: type 2 through low impact farming. Higher landscape diversity with lower productivity. Incorporating semi-natural elements throughout farms, but a low turning over of productive land into non-managed lands.

Agroecological intensification typology (Garbach et al, 2016)	Large expansion of precision Agriculture and well managed conventional agriculture. Using high-tech monitoring and application technologies and techniques to make input-use efficiency gains, reduce biodiversity impacts of fertilizer and pesticide use, while achieving substantial yield gains.	Precision & Conservation Agriculture (FAO, 2025) where the latter helps to sustain essential ES for the wider region, e.g, maintaining water retention near cities, or as buffer zones between agricultural areas and strongly protected areas. A "consider all options" approach to sustainable intensification (Royal Society, 2009).	Predominately Organic Agriculture & Conservation agriculture More land under cultivation making up for lower yields per farm. Comparatively low mechanization and low inputs, highly nature dependent farming.
Animal protein consumption reduction method	Market still seeks to cater to the preferences of the global middle class but increasingly seeks technological innovations that can substitute meat for novel proteins. Technological innovation in the meat production system lower carbon and land-use footprint of meat production. Sustainable intensification on remaining livestock land.	Meat consumption reduced via taxes and global governance incentives to incentivize people away from meat, but there is less focus on faux-meat products or novel protein sources. Plant-based protein sources are preferred.	Livestock play an important role in global food cultures, organic fertilizer production etc. Heritage and climate resilient breeds. Meat is a prized commodity, eaten rarely, and a major component of the cultural life of communities. Herd sizes remain small, and farms are mixed use with both livestock and arable production. Livestock density is generally low and dependent on regional environmental capacity.
Landscape Scale usage patterns (Rodriguez et al, 2024) and drivers of specialization	Intensive and specialized field types. Monocropping and low non-crop diversity on field in order to keep yields high and achieve cost efficiency. Market drives variability in specialization on landscape scale, some areas devoted to single crops, others highly specialized. Market driving	Intensive and diversified. Crops are grown where there the lowest environmental cost and environmental conditions can bear the intensification of production. Large or middle-sized farms allow efficient allocation of resources. Some monocropping in intensive production regions.	High levels of crop diversification. Communities promote climate resilient and heritage varieties which would not be selected on a market led marginal utility bases. Landscapes are patchworked with small farms growing crops suited to community need and ecological suitability. Increased use of commonages.

	monopolization leading to very large farm sizes which can be efficiently mechanized.		
Determinant of Crop Types	Market determined, catering to taste and purchasing power globally, with substitution towards sustainable and resilient form	Focus on staples and ensuring global prioritization of calories and nutrients needed to ensure achievement of global planetary health diets	Dependent on local contexts, appreciative of different foodways. Species diversification
Yields (Weindl et al, 2024)	Highest yield increase in OECD and non OECD countries	Stable yields in OECD and EU until 2050, decreasing after 2050. Medium increase in non OECD	Increase in low productive systems. Stable to lower yields in efficient systems, resulting in decreasing yields in OECD countries and lowest increase in non OECD countries
Ecosystem Services on farms & pollination	Focus is on providing efficient pollination delivery to maximize its benefits for crop production / yields through a marketized approach to providing pollination services, e.g., through honey bee hive transportation to service crop growing areas.	Least dependent pathway on pollination, less important owing to precision agriculture, and therefore reduced need to restore on-farms for pollination services. Likewise this pathway has high dietary shift towards plant-based foods and the majority of stable crops are self-pollinators. High levels of spatial separation between agriculture and unmanaged lands reduces effectiveness of wild pollination.	Most pollination and ES dependent pathway. Diverse on farm vegetation. Insectary strips and wide field edges and hedge rows supports on farm pollination and natural pest controls. High on farm carbon storage through low till soil building techniques.
Mechanization/L Labor (Vittis et al, 2022) And Digitalization	Substantial high-tech technological incorporation. laser levelling, global positioning systems, and spatially explicit yield monitors to improve input use efficiency and reduce environmental harm associated with fertilizers, pesticides, and above-ground irrigation. High degrees of automation reduce	Focus on bridging the mechanization gap to expand agricultural mechanization in developing nations. Strategic/planned production to ensure developing nations can afford to mechanize. Moderate level of rural labor saving ensuring developing nations are avoiding a Lewis trap; redeployment of rural workers into conservation and restoration work. Focus is on developing sustainable agricultural	High labor-intensive production systems. Comparatively low increases of mechanization. Focus on artisanal mechanization designed to meet specific local conditions and needs of regionally specific agroecological systems. “Appropriate technology” (Sianipar et al, 2013) Farm data collection remains low, focus is on valorization of local and traditional knowledges, and labor intensive techniques which promote specialist

	labor across the system. Farming collects vast amounts of privatized data which feeds into proprietary ownership. Farm labour high skill technical profession	mechanization (Sims et al, 2017) techniques to support relatively low till conservation agriculture. Commitment to public data useful for systems planning.	granular knowledge of own farms. Farming is a highly skilled profession with ecosystem specific knowledge, but low technologization.
Pesticides and Hazardous Chemicals	Achieving the production efficiency gains needed to support the high consumption in this pathway means that pesticide use is comparatively high compared to other pathways, but as the externalities of these products are price the market drives the development of less harmful alternatives.	Pesticide remain a feature of agriculture where their usage is necessary to make improvements to the worst off, and where there usage is consistent with the ecological capacity to absorb the impact.	Shift away from pesticides towards organic production. While this causes overall productivity to fall, this is accounted for by a reduction in per capita consumption.
Fertilizer use	A result of the pricing of nutrient loss is that farmers have to account for potential nutrient loss when choosing to use fertilizers. This leads to an incentive for fertilizers to only be used where doing so remains profitable once the cost of nutrient loss credits are factored in. This leads to the cost-efficient solution of fertilizers being allocated to the most utility-effective locations and uses.	Global fertilizer budgets can be centrally set and then distributed to regions/production systems which are determined to have the greatest need for it and strategically prioritized to ensuring a stable and affordable supply of global staples. Balancing need to generate high yields to benefit global worst of with ensuring use occurs where there is ecological capacity to bear it.	Lowest artificial fertilizer use globally (US EPA, 2007a). Global share of fertilizer use is distributed on an egalitarian/ needs-based basis – either per hectare, per capita, or distributed to the most effective uses and the final products of which are distributed fairly. There may be unequal uses of fertilizer globally between the regions – with different regions consuming more or less depending on agricultural conditions or needs to meet a local dietary specificity.

Nutrient Loss (Sutton et al, 2013) KMGBF 50% Reduction target	The central driver of nutrient loss is seen as the fact the market had no incentive to factor it into its pricing. Novel financing PES programs are developed (Including Nutrient/Water Quality Trading from non-point sources) so that producers have to account for nutrient loss when siting agriculture and creates an incentive to find ways of reducing nutrient loss on farms. 50% reduction target achieved globally.	The focus in this pathway is on changing how governments incentivize and disincentive global fertilizer uses to avoid over use in regions where there is a lack of capacity to absorb nutrient loss, and where possible to increase use in regions where the ecology can support an increase and where doing so can have positive food production outcomes that support the global poorest. The current regime of global subsides for fertilizer use that vary country to country may be altered, to promote fertilizer use in regions where it is ecologically sustainable and benefits the worst off, and ceasing harmful subsides elsewhere. 50% achieved globally.	Nutrient-loss is minimized through a global transition to a labour intensive organic farming regime (Muller et al, 2017). Organic agriculture refrains from using synthetic fertilizers and pesticides, promotes crop rotations and focuses on soil fertility and closed nutrient cycles. A global shift to organic and low till agricultural systems successfully reduces nutrient loss from farms. A patchwork agricultural landscape interspersed with forests and wetlands plays a role in capturing and sequestering nutrient runoff from farms. 50% achieved region to region, which some trading between regions to support

Table 17. Trade and Intermediate Value Chain Assumptions

VITAL-PATHS-FOOD: Trade and Intermediate Value Chain Assumptions			
	International Market Innovation	**Global Sustainability Orchestration**	**Local Commons Stewardship**
Food Loss	Biodiversity offsetting programs raise the cost of establishing new agricultural lands leading to intensification of production, but also efforts to lose less food before products reach markets. This incentivizes the market to invest in reducing post-harvest loss, including through novel propriety technologies for food storage and transport techniques. Genetic technologies and new preservative techniques reduce spoilage, and technological advancements lead to more efficient processing stages with less loss.	Reducing post-harvest food loss is identified as a major aim of global overseas financing. Funds are established to allow global south producers to access financing for new equipment and infrastructure improvements. North-south technology transfer is facilitated through a weakening of intellectual property laws on key agricultural technologies, allowing regional production to be established. Global infrastructure investment in establishing adequate storage and transport facilities.	Short supply chains and close to harvest consumption means there is lower overall risk of post farm-gate loss in transport and storage. Food is consumed locally and seasonably. Potentially a modest increase in on-farm loss through increase in pests and the risks of shifting to a high-labor demand agricultural system (if labor needs are unmet). Communities in the global north assist in transfer of resources for infrastructural improvement abroad to halt waste.

Sustainability Standards	Competing sectoral standards and a sustainability conscious consumer base drives and upward pressure for companies to adopt ever stronger regulations. Companies make pledges and adopt good practice codes to reassure consumers that their products can be trusted. Likewise, intermediate actors such as whole sellers are motivated to purchase from sustainable producers in order to hedge against the supply chain breakdown that would occur if there was an ecological disaster. Sustainable products are seen as a "safe bet" by wholesalers and distributors.	Global organizations standardize sectoral minimum standards and create international compliance regimes. The focus is on legislative simplicity and one-size-fits-all regulations. A central regulatory bureau is instituted to coordinate standard setting and is given broad coercive and incentivization powers to ensure compliance from supply chain actors. Products assessed to be overly harmful and difficult or prohibitively expensive to reform are subject to vice taxes to drive down demand and leverage biodiversity finance.	Communities and regions are given increased autonomy to decide how to regulate their activities and adopt standards that are fitting and appropriate to their values and particular ecological settings. Protected origin designations are used to ensure that foods and resources are from genuinely local sources and that the products meet the high expectations of local communities. There is little standardization between regions which acts as a barrier to easy trade, and creates pressure for local production. Communities try to ensure that when they are buying global products they conform to their preferred standards, via EUDR style regulations
Distribution networks	A competitive market is thought to be the best way to ensure that distribution networks are efficient. Long supply chains are needed to ensure production occurs in the most efficient growing regions. "Just in time" principles continue to be practiced and keep prices down, but increased computational power and moderate private investments into transport infrastructure lessen the wastages from this.	Global institutions and governments play a larger role in procurement in the food-biomass supply chain to ensure that prices are kept fair and that producers in the global south are able to keep a greater share of the value produced. Nonetheless supply chains remain long to support an intensification of production in the most suitable regions.	Novel means of sharing resources within communities are developed, including community kitchens and food hubs. Farm-to-fork distribution with increased connectivity between producers and consumers. Every town has a vibrant farmers market. Limited global trade for essential goods operating on a peer-to-peer basis.
Global trade	Washington Consensus preserved – global trade liberalization. The lowering of trade barriers are thought to be the best way to stimulate competition and innovation, and to keep prices low. This allows specialization across borders	Global interconnected trade to achieve economies of scale to secure a high enough production to continue to progress on welfare goals. In key sectors of the global economy states and super-state organizations step in to coordinate distribution and ensure that supplies reach those who are worst off and progress us made on social aims.	Limited global trade as production is increasingly on-shored, owing to a consumer preference for locally produced goods. Needs-based economy means that markets are less relied on for distribution within regions. Global exchange of good scontinues for essential products that cannot be produced locally, organized on a bi-lateral basis.

Table 18. Terrestrial Protected Areas Assumptions

VITAL-PATHS-FOOD: Terrestrial Protected Areas Assumptions & KMGBF Target 3			
	International Market Innovation	**Global Sustainability Orchestration**	**Local Commons Stewardship**
KMGBF Target 30% Conserve 30% of Land Water and Seas	30% achieved globally with PAs on economically efficient land particularly in the global south, with due consideration while factoring in a method of pricing of ecosystem service provision & NCP factored into assessments of economic efficiency. Restoration is considered alongside Protected Areas Preferred restoration in least commercially viable managed land	30% met or exceeded globally in scientifically determined conservation optimum locations with some mediation and exemptions are granted to ensure that egregious or uncompensatable burdens are not given to the globally worst off. "Conservation optimal" determined by objectives of maximizing utility for nature, focused on connectivity and preserving intrinsic value.	30% shared equally between nations/communities, with some global north countries taking on additional burdens in respect for global equality and historical responsibility.
IUCN Protected Area Taxonomy (IUCN, 2008)	Focus on sustainable resource access and targeted PAs to manage extinction risk and ES provision. "Managed Resource Protected Areas (6)" and OECMs, plus targeted "Habitat/Species Management Areas (4)" to guard against loss of particularly vulnerable species.	30% target met with comparatively few but expansive areas of highly protected sites. Preference for: "Strict Nature Reserve (1a)", "Wilderness area (1b)", and "National Parks (2)".	Focus on achieving cultural goods through National Park (3)", "Protected Landscape/Seascape (5)" Large component of OECMs that allow people to continue living and working in PAs.
Biodiversity offsetting	Global Offsetting permissible to allow the market to identify pareto-optimal solutions. Companies can seek to make high marginal returns by offsetting where it is economically efficient to do so. Flourish market for offsets and competing standards.	Rejection of biodiversity offsetting due to focus on intrinsic value of nature. Natural areas are viewed as unexchangeable/non-fungible. The market plays a minimal role in locating protected areas compared to expert top down planning.	Limited- "local for local" "like for like" offsetting permitted within geographically constrained bioregions and across areas of a single habitat type. Offsetting regimes offer a premium rate for finding replacement locations nearby to ensure cultural link with nature is maintained.
Compensation baseline (Armstrong, 2024)	Willingness to Accept: Compensation for lands lost to protected areas is a calculated on a "willingness to accept" principle - i.e., the price as determined by the market value of the land with minimal governmental regulation preventing the use of status quo baselines where the status quo is clearly below the poverty line.	Anti-Poverty Baseline: Compensation calculated from a moralized baseline based on what occupants *ought* to be earning if they were earning enough to progress towards meeting global goals of poverty eradication. Wealthy nations establish a Global Conservation Bank, which is empowered to purchase debt below market rate for especially debt-laden	Egalitarian: Compensation calculated against what the occupant would need to be earning in order to live an equal and sustainable standard of living. . Historical responsibility leads to countries in the global north compensating nations in the global south for the costs of taking on protected areas needed for halting global biodiversity loss and essential global

		biodiverse countries even when more efficient investments could be achieved elsewhere.	ecosystem services.
Subnational Scale & Protected Area Connectivity/SLOSS (Fahrig et al, 2022)	Agricultural intensification increases the space that can be devoted to protected areas. Ecosystem service provision is priced into calculations of land value, meaning some PAs are sited to ensure ES provision for instrumental purposes, e.g., water regulation and carbon storage. Moderate connectivity between sites. Connectivity not an objective per-se, size and frequency of PAs determined by global economic efficiency. Islands of highly protected biodiversity areas strategically placed to make room for agriculture while preserving biodiversity across the landscape. Accurate pricing of global NCPs will inevitably mean some large, connected areas will be needed, for instance to protect global carbon stores. Highly protected minimum viable space requirement islands to protect highly disturbance prone species. Islands of protection in key ES provision areas.	Agricultural intensification increases the space that can be devoted to protected areas and protected areas are promoted in sites which prioritizes the best results for biodiversity. Protected areas are large and interconnected with enough space for ecosystem processes to occur with minimal human oversight. Highly connected landscapes: Single large conservation areas (the conservation status quo) thought to be best way to preserve biodiversity. Focus on rewilding to defragment habitat areas and to focus on the preservation of contiguous core areas of habitat.	Extensive low impact farming and forestry leaves comparatively reduced space for strictly protected areas, and much of the 30% total is less strongly protected that in other pathways. PAs are focused on preserving culturally significant landscapes and emblematic species. Communities have a strong degree of autonomy over where PAs are sited and determine sites that best promote local welfare, while ensuring that no community members take on an undue share of the burdens. Medium to low connectivity. Extensive agricultural strategy breaking down the divide between single-large/several-small by breaking the link between protected and productive areas in terms of biodiversity impact. Landscape may still be patchwork of productive and semi natural areas, but with corridors of habitat to facilitate connectivity
Global Distribution	Protected areas to be sited predominately in the Global South. Protected areas in Europe and North America are sited in the cheaper lands in the high latitudes, as well as in locations needed to provided essential ecosystem services. Pricing of ES ensures that these locations are protected.	PA distribution in biodiversity rich, or conservation essential regions while ensuring that enough land is land remains available for development. As biodiversity is concentrated in the tropics, many PAs have to be sited there to prevent extinction. But extensive PAs also exist in high latitudes and at key locations in Europe and North America. Extensive cross-border spanning PAs.	Egalitarian principles both globally and locally lead to 30% total being distributed country by country, with some communities in the global north offering to take on additional space to minimize costs to development for countries in the global south.
EU	PAs in the EU are located in areas where the ecosystem service and recreational values are high enough to offset their relatively high price. Protection is moderate and focused on ensuring long term resource sustainability and preserving highly unique	EU has a few relatively high protection national parks, with the focus on strategic planning to ensure interlinkages and spatial expansiveness needed to allow natural processes to occur with minimum human management. The main way the EU contributes to PAs is	EU is patchworked with OECMs and moderately protected areas in culturally significant sites, and to support provision of pollination and water management services. PAs may have some economic uses within them and focus on developing rich

	landscapes. PAs may be disconnected and allocated to low agricultural value land, such as abandoned farmland. EU supports PAs abroad through intensification of onshore production leading to less displacement pressure.	by providing funding, expertise, and compensation payments for PAs abroad	biocultural landscapes with high amenity and aesthetic value. EU supports PAs abroad by accepting historical responsibility for biodiversity loss, cutting consumption and onshoring production.
Exclusion	IPLC valued as having important knowledge for making accurate assessments of the ecosystem service value of PAs, and are given protections as the best (and often lowest cost) managers of the territories they occupy. In some cases this leads to a formalization of customary tenure where that is useful to ensure the market can properly compensate IPLC for ES provision. As PAs are focused on provisioning IPLC management not seen as a major barrier.	Comparatively higher risk of displacements owing to stronger PA protections and a focus on creating interlinkages between PAs. Risk are mediated by a global commitment to protecting IPLC rights to exist in place. However comparatively high compensatory payments are offered, some local communities do relocate to make space for new PAs. IP have agreed right to exist in place, but LC on edges more at risk of displacement	IPLC given significant new authority to manage their territories and are able to ensure against exclusionary PA policies. IPLCs are respected as the best managers of their PAs, and their connection, knowledge, and experience is valued. Restoration of IPLC political control over their territories is understood as a cornerstone of biodiversity positive change.

Table 19. Sustainable Consumption Assumptions

VITAL-PATHS-FOOD: Sustainable Consumption Assumptions & KMGBF Target 16			
	International Market Innovation	**Global Sustainability Orchestration**	**Local Commons Stewardship**
Consumption Overview	Consumption remains higher than other pathways. Link between consumption and biodiversity loss broken/decoupled by improved technological and systems efficiency. New products and techniques allow consumption to remain high. Low active redistribution. Low government coercive authority to sustainable consumption is lead by creating pull factors. Market incentivizing customers onto sustainable products, and governments creating incentives for consumers to switch.	Consumption reduced and reprioritized. Overconsumption in high consuming regions today reduced to make space for raising consumption in others and prioritarian redistribution of goods. Focus is on creating push factors to drive down consumption of high impact products via government action/regulation, but raising consumption to eliminate poverty elsewhere.	Consumption reduced via life-style changes. Overall demand down reducing the need for technological change and mitigation of impacts. Inequality between regions, but progressing towards equality within regions, while ensuring all regions are within a min-max consumption window. Different regions are consuming different products but overall inequality reducing globally, especially in presently high consuming regions. Limitarian focus on halting overconsumption.
Mitigation Hierarchy	Focus is on *substitution* of biodiversity loss causing products today with new or alternative products that do not have negative biodiversity impacts, allowing for a transformation without substantial behavior/lifestyle change or a large reduction in	Global Stewardship aims at a *Reduction* of biodiversity impacts of consumption through increased whole system efficiencies. The impacts of consumption are offset by greater increases in biodiversity from	This pathway aims at the *Prevention* of biodiversity loss and damages through an overall reduction of per capita consumption globally, especially of currently over-consuming regions in the global north. While there is a

	overall consumption. This decoupling of consumption from biodiversity impact is made possible through new techniques of production and new sustainable products.	protected and restoration areas that are made possible by production intensification.	switch to less damaging forms of production (and sustainable products to consume) particularly organic farming, this is facilitated by an overall reduction in consumption.
Consumer Waste/Recycling	Lowest reduction in consumer waste. Consumption remains high and market has limited interest in what happens to products post purchase. Sustainability gains are achieved elsewhere in the system. Advances in food-tech reduce product spoilage. Customer interest in sustainability opens a market niche for redistributing end-of-shelf-life products. Big data improves efficiency of supermarket ordering systems to limit point-of-sale waste.	High increase in consumer waste reduction and recycling of waste. Government focusses on whole-system efficiency and legislates for extensive public waste recycling programs and composting. Public provisioning programs, "public restaurants" lower home cooking waste and redistribute surplus to benefiting worst off.	High increase in waste reduction through a shift in consumer values and a shift to highly local and traditional diets and food practices that value using resources frugally and ensuring very little is wasted. Consumers focus on eliminating waste at home and in the community. Resources are used sparingly and products are "built to last".
Sustainable Choices	Government plays a light touch role in promoting sustainable practices, preferring to let the market act unimpeded and respond to demand for sustainable products from an increasingly ecologically conscious public. Governments may influence sustainable product demand through nudges and education.	The state plays a key role in incentivizing a shift to sustainable consumption, by using coercive means (e.g., taxes, fines, and other "stick" measures) to shift both production and consumption in sustainable directions. There is a reduction of consumption in the global north to create ecological space to support development in the global south, particularly reductions in undernourishment.	Communities and their governing make strong voluntary commitments to reducing consumption. In particular communities in the global north recognize their historic over consumption of good, and make especial efforts to transition to a planetary health diet and cutting luxury consumption.

Table 20. Bioenergy & Carbon Capture Assumptions

VITAL-PATHS-FOOD: BioEnergy and Carbon Capture Assumptions.			
	International Market Innovation	**Global Sustainability Orchestration**	**Local Commons Stewardship**
Scale of BECCS	Consumption remains high in this pathway and so does the demand for energy and consequently carbon capture.	Moderate use of BECCS to support hard to abate industries. Carbon capture mostly achieved through non BECSS methods.	Consumption is low which largely negates the need for substantial quantities of BECCS. Carbon removals were achieved elsewhere.
Locations	BECCS is sited where the market deems it effective to do so – i.e., where the price of land and the opportunity costs to developing BECCS instead of productive uses of the land is outweighed by the pricing of delivering new carbon sinks.	Expansion of BECCS is constrained by new strongly protected areas. While energy use remains moderately high to meet social/developmental aims, carbon savings are achieved through grid improvements and international	Reduction in consumption substantially negates the need for BECCS as energy demand is highly reduced. No substantial landscape impacts. Some household uses of biomass fuels, but low use of wood as a fuel.

		coordination in energy production, including renewables production and nuclear energy.	
Other negative emissions methods	Enhanced weathering on intensely managed farm lands and forests, and on BECCS plantations – increasing creating co-benefits for biomass production. Innovation and strong market for carbon credits/offsets drives innovation in direct air capture technology with major roll-out by end century reducing need for BECCS.	Afforestation and Reforestation play a major role in capturing carbon and increasing the size of the global carbon sink. Ecological restoration including peatland restoration also has a major role to play. Some enhanced weathering and other novel carbon capture technologies play a role.	Soil building through organic and low-till agricultural techniques, including peasant led farming. Afforestation and reforestation, including forest restoration measures that convert fast growing highly managed forests into forests with greater understory.
Carbon Offsetting	Offsetting determined by the market with a healthy market for carbon credits in order to determine the optimal use of negative emissions, and negative emissions usage rising to meet demand. The market is able to determine the correct balance between forestry/agriculture/beccs by correctly pricing ES value of storing carbon.	Offsetting limited to strategic and hard to abate sectors. BECCS can only be used if strategic industries are unable to mitigate emissions. BECCS usage is continually reviewed to ensure that it does not impact food security or worsen biodiversity loss.	Reduction in overall consumption and a higher on-farm capture of carbon means that the terrestrial carbon sink expands to the point where it can adequately capture emissions without a need for a strong carbon accounting system. Focus is on mitigation through consumption reduction.

Table 21. Governance and Institutions Assumptions

VITAL-PATHS-FOOD Assumptions: Governance			
	International Market Innovation	**Global Sustainability Orchestration**	**Local Stewardship**
Transformative Governance Level	Libertarian reshaping of nation states globally, with states breaking down trade and regulatory barriers allowing goods and services to flow seamlessly around the globe. National level governments enter into new free-trade agreements that allow for a global restructuring of global food and biomass value chains, allowing the market new opportunities to find efficiency gains. The government sets market conditions by creating incentive regimes to allow ecosystem services to be priced, and to regulate offsetting regimes. The expertise of large corporate actors is highly valued and indispensable, and these actors play a key role in facilitating governance.	Supernational organizations including then U.N. play an increased role in governing the transition. Biodiversity is understood to be a global issue requiring global governance, and states recognize that managing a transition to a biodiversity positive future while making progress on global social development goals will require unprecedent levels of international global cooperation. States come together to empower new global governing bodies and institutions which have substantial powers to coordinate action including managing affairs usually left to states themselves.	Governance is substantially devolved to smaller self-determining jurisdictions. There is a wide diversity of governing organizations and different communities find plural ways of legislating and governing for themselves, in accordance with their vision of procedural justice. Regions cooperate with each other bilaterally to share and exchange the goods which they produce, and coordinate production to meet each other's needs.
Role in Supporting Transition	Governments remove barriers to free trade and innovation needed to allow the technological development and growth needed to break the link	Governing actors play a major role in coordinating transition efforts through expert-led command and control policies. The	Government supports the transition by guiding production and cultural development in nature positive directions. As

	between development and biodiversity loss. The government mostly steps back to allow the market to find efficient solutions, intervening to enforce negative environmental externalities being priced into market decisions. Likewise, the government ensures that some progress is being made on social goals, though it prefers to find means of leveraging private actors to do so.	government has strong enforcement powers which are coordinated across borders. Global governing institutions rely on the expert advice of coordinating boards of scientists and economists to make planning decisions and ensure that actions taken are done in a way which maximises positive outcomes for biodiversity and the globally worst off.	power localizes, each governing authority exerts control over a smaller area – which allows the government to make very targeted and regionally specific interventions to support biodiversity positive action in a way amenable to the needs of its local community. However, there is comparably less coercive authority to ensure compliance between regions – and relations between polities has to be conducted on the basis of good will and solidarity. Governments are values led and try to make bilateral agreements with polities who they feel share their values.
Relationship with Markets	Strongly pro-market pathway. Trade liberalization is seen as key to enabling technological development needed to support global development and decouple growth from biodiversity loss. Government plays a role setting conditions for environmental markets, PES, and biodiversity offsetting.	Economic coordination between states facilitated through multilateral agreements, central planning, global taxes on certain products to reduce consumption. Global development banks facilitate technology transfers and infrastructure development. Multi-lateral agreements are signed to organize cooperation. Markets still exist but are regulated globally and states and global institutions use their power to ensure the benefits go to the worst off.	Needs-based post growth economy. Communities share goods amongst themselves to ensure all needs are met, and the world is substantially more equal. Local markets permitted but local polities stepping in to support a shift toward greater equality within polities themselves.
Democracy and Procedural Justice	Government is liberal and democratic and recognize the formal equality of their citizens. People are able to exercise their will through consumer choice, and one of the functions of the government is in ensuring competition in the market place through a monopolies commission, which ensures that private companies are forced to innovate and make biodiversity positive efficiency gains.	Upscaling governance to global actors is a major coordination challenge, and individual citizens are now further removed from important decision-making power. While global institutions are democratic, authority is increasingly devolved. Global institutions increasingly rely on experts to make decisions and there is a weakened role for public consultation – something thought to be too challenging at a global scale, and also an	Smaller scale polities open up the possibilities for new types of governance to emerge, including highly participatory directly democratic forms. Important decisions may be made by consensus, and citizens have powers to recall their officials if they fail to meet their promises to facilitate equality or meet pre-agreed targets for the transition.

		impediment to taking swift and decisive action.	
Recognitional Justice	A smaller role is directly played by the state meaning that additional recognitional justice gains are made voluntary and dependent on the business practices of private companies. The predominant way in which people are recognized is as market-actors who make their individual preferences known through their purchasing preferences. Market actors may cater to the recognitional needs to groups or individuals (e.g., local/cultural dietary preferences) to the extent that they are willing and able to pay for them.	International Order and Global Governance Institutions are liberal in outlook and willing to exert coercive authority to enforce human rights and international law. States see the most practical way of enacting prioritarianism is through liberal internationalism, and a formal respect for global human rights. However, this may overlook the specific needs of subaltern groups in the pursuit of formal liberal equality before the law. Governments also commit to recognizing the rights of nature and find novel means of representing these in liberal government institutions.	Devolution of authority means that previously subaltern groups are able to have a greater say in the governance of their communities. Additionally the governments focus on supporting a cultural relationship with the natural world entails supporting new and experimental nature positive ways of living. IPLC are particular beneficiaries, receiving the option of forming independent sovereign polities. However, the active role that governments now play in acting as cultural custodians means a greater deal of scope for governments intervening in private lives and ensuring cultural conformity within regions, in a way liberal government would have guarded against.
EU	In this pathway the EU facilitates free trade between its members, liberalizing its regulatory institutions, and negotiating for an expansion of free trade with countries globally. The EU is a technological leader, pioneering new agricultural and ecological restoration techniques, as well as novel products. The government promotes investments into these key sectors using market incentives. There is a robust EU-wide ecosystem services and biodiversity offsetting system, which allows the market to find EU-wide efficiencies in locating agricultural, forestry, and protected area sites. The EU sets the market conditions for these programs to ensure ecological outcomes are achieved.	The EU plays a global role in coordinating the ecological transition, using its governmental, bureaucratic, and scientific-technical expertise to play a central role in the design and implementation of new supernation governmental bodies. The EU acts as a model for how a successful system of regional multi-national coordination can be implemented, and EU planners and policy makers have key skills to be shared in designing new cross-border cooperation efforts globally. The EU government facilitates the transfer of finance and technology to support biodiversity positive actions globally, including onshoring of production to reduce its global ecological footprint. It acts a strategic ecological planner and takes on new responsibilities and centralized authority to	The EU sees substantial regional devolution, and supports states in restructuring political authority, while providing regions with a forum for political negotiation and a means to coordinate production between regions and manage trans boundary problems. The EU allows regions a greater deal of autonomy to make environmental planning decisions. Globally the EU supports regions in making global links and supporting trade deals, as well as facilitating reparations payments to support conservation abroad and account for historical responsibility. The EU is a loose confederation of small regional polities, and plays an advisory and role with little coercive authority to intervene in its member nations affairs.

		let it play an active role in coordinating and redistributing production.	

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