Hidden costs of the Swiss Agrifood System

Case study for the State of Food and Agriculture Report of the FAO - SOFA 2024

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March 5, 2025

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Summary

Agriculture and food systems are a central basis for our societies, providing food and a number of other services such as rural employment or landscapes with recreational value. However, global agriculture and food systems also have large environmental, social and economic impacts, contributing to biodiversity loss, climate change, water scarcity, precarious working conditions and unhealthy dietary patterns. The scale of these adverse impacts is significant. It is thus of paramount importance to support pathways towards agrifood system transformation, where these impacts are significantly reduced.

One approach that can support this is true cost accounting, i.e. the estimation of the hidden costs of the agrifood system. Hidden costs are those costs of production and consumption decisions that are not accounted for when taking those decisions and that are borne by third parties or by society at large or later in life (an example are the costs of climate change impacts that are not accounted for when taking farm management or consumer decisions resulting in GHG emissions). True cost accounting thus puts a price tag on the adverse impacts mentioned above. This helps to increase awareness by relating them to the economic narrative of social welfare and GDP generation or rather, in the case of these adverse impacts, welfare and GDP losses.

The State of Food and Agriculture Report by the Food and Agriculture Organization of the United Nations FAO from 2023 ("SOFA 2023") focused on the hidden costs of agrifood systems globally, based on country level estimates of these costs for a number of categories, where globally consistent data was available. The system boundaries for this are territorial regarding food system activities, i.e. reporting the hidden costs of the agrifood system in a nation, covering the impacts from domestic production to consumption (also if the impacts arise abroad, e.g. from GHG emissions or nitrogen runoff into water bodies beyond the country borders), but not covering costs from imported food, feed, fertilizers and other inputs.

This case study here refines the SOFA 2023 estimates for Switzerland and complements them with additional topics not covered yet in SOFA 2023, in order to identify the most pressing challenges and opportunities of the Swiss agrifood system in terms of externalities and recommendations of potential entry points for its sustainable transformation.

The assessment of the SOFA 2023 results showed that for Switzerland, the estimates for the categories covered in SOFA 2023 can largely be taken without refinement – with the exception of GHG emissions, where Switzerland, based on most recent scientific studies, uses a six times higher value for the social costs of greenhouse gases, which, with some conservative safety margin for methodological uncertainties results in about triple costs of GHG emissions.

Besides checking and refining the values for the categories covered in SOFA 2023, additional categories lacking in the SOFA 2023 estimates need to be added. Most central are the hidden costs of biodiversity losses, amounting to about 7.5 billion CHF, i.e. almost a third of the original estimate. Furthermore, health costs in SOFA 2023 consider

only costs of noncommunicable diseases due to 'unhealthy diet' and do not cover direct treatment costs and immaterial costs from suffering and lower quality of life that amount to 8 and 9 billion CHF, respectively (where counting direct treatment costs as hidden is particularly contested).

It is important to note that some of these estimates may be subject to some double counting, such as the additional costs treated to biodiversity with the originally covered costs from nitrogen emissions and land use. The part of these costs potentially affected by double counting is however an order of magnitude lower than the newly added biodiversity costs and it is hence deemed not a major problem. Furthermore, we generally adopted a conservative approach, using rather lower than higher estimates where uncertainties are particularly high, such as for land use change, where we use the original estimate of SOFA 2023 albeit one could argue for considerably higher costs. This would then however make the issue of double counting more relevant as well, which is avoided by using the original, lower estimate.

The estimates show that total hidden costs of the Swiss agrifood system including these additional costs amount to about 32 billion CHF in 2020 (while the original estimation of the SOFA 2023 report without these additional costs amounts to about 21 billion CHF in 2020), whereof the consequences of unhealthy diets amount to 17 billion CHF, followed by biodiversity losses at 7.5 billion CHF, and GHG emissions and nitrogen emissions at about 3.1 and 2.9 billion CHF, respectively. The following table summarizes these results.

For completeness, the table also reports the hidden costs related to imports of food, feed and other agricultural inputs. In addition to this table, potential hidden costs related to biased subsidies, border protection and other incentive schemes should be analysed. These are particularly controversially discussed, very difficult to quantify and hence not reported here.

Category	**SOFA 2023 value (billion CHF)** [1]	**Refined/ complemented value (billion CHF)**	**Cost difference SOFA 2023 to refinement**
An entry "-" means that this value has not been estimated due to already being covered by other categories, lack of data or negligible size; for detailed explanations, see the corresponding sections in chapter 6; there, in section 6.4.1, a detailed version of this table with explanatory notes can be found.			
Refinements			
Health – basic estimate	17.1	17.1	0
Health – additional costs	-	8 (direct health costs) 9 (immaterial health costs)	8 9
GHG emissions	0.9	3.1	2.2

[1] Values are in billion CHF; to derive 2020 US$ PPP values, they have to be divided by the appropriate PPP conversion factor of 1.105 (World Bank, 2024).

Nitrogen emissions	2.9	2.9	0
Water use	0.0013	0.0013	0
Water pollution	-	-	-
Poverty	0	0	0
Undernourishment / Malnourishment	0	0.57	0.57
Land use change	0.22	0.22	0
Complements			
Phosphorus	-	-	-
Soil health	-	0.17	0.17
Biodiversity	-	7.5	7.5
Pesticide use	-	-	-
Antimicrobial resistance	-	0.15	0.15
Animal welfare	-	0.11	0.11
Summed values			
Total SOFA 2023	**21.1**		
Total refinements plus complements		**31.8** (**48.8** when including additional health costs)	
Total difference between refinements/ complements and SOFA 2023			**10.7** (**27.7** when including additional health costs)
Imports (reported as a separate category due to different system boundaries than used for the other categories)			
Imports	-	6.7	6.7

The high costs of unhealthy diets are largely driven by the high per-capita productivity in Switzerland, as the estimates are based on the productivity losses due to noncommunicable diseases from unhealthy diets (unhealthy diets lead to increases in non-communicable diseases such as cardiovascular diseases or diabetes; these result in an increase of sick days for employees with corresponding reduction in their labour productivity, which results in high GDP losses and thus high hidden costs, given the high labour productivity in Switzerland).

Generally, the hidden costs in the other categories than health are considerably lower. These lower estimates should however not automatically signal lower importance. Biodiversity loss, nitrogen emissions and GHG emissions amount to significant values as well, and the relatively low values for water use and water scarcity or antimicrobial resistances, for example, rather show that the problem is not yet big – but the related costs may increase in the future. Hence, close monitoring of currently less important categories is important to avoid them becoming relevant in the future.

Having the hidden cost estimates at hand, the central task is to identify entry points for action. The aim was not to suggest concrete policy instruments but rather to provide a sound basis for a subsequent process that may identify such. Key for identifying entry points for action is to attribute the costs to the "cost producers", identifying the underlying drivers as well as the relevant interdependencies. Regarding dietary health impacts, it is clearly up to individual consumers to decide what they eat, and the following most important unhealthy dietary patterns can be named: diets low in whole grain, high in meat, low in legumes, high in processed meat, high in sodium, low in fruits, high in trans-fatty acids, and low in vegetables. However, individual consumption decisions are never done in a void space and food environments play a central role. Addressing the responsibility of the whole food sector, advertisement and retailers is central, as well as the role of education, dietary counselling and gastronomy.

Regarding biodiversity, it is central to identify the key drivers in the context of land use change and landscape structure, use of pesticides and fertilizers. Regarding GHG emissions and nitrogen, attribution can be derived from the GHG inventory and nitrogen balance calculations. This illustrates the importance of the livestock sector for nitrogen use, importantly also highlighting the role of high livestock numbers fed on imported feed and the cropping patterns with large cropland areas under feed cereals and forage maize. Such differentiation and attribution is central when addressing the hidden costs of imports and food waste, where some commodity categories are likely to dominate in certain cost categories.

Importantly, the cost producer is not necessarily the decision maker to be targeted directly. Imagine pesticide use in apple production to ensure meeting certain visual quality criteria from retailers. In this case, the farmer is clearly the cost producer applying the pesticides, but the drivers behind are the retailers' requirements and consumers' expectations regarding visual quality criteria. Working on the latter would be the more central leverage point than working only on the pesticide applications without addressing this underlying driver.

All this is to be assessed in a context of complex interdependencies. Accounting for them is important to build on potential synergies between different topics and to avoid trade-offs, where possible. To name just few examples, one key interdependence links various aspects via the high nitrogen use levels prevalent in Swiss agriculture (e.g. large livestock numbers, high biodiversity costs, health aspects of ammonia emissions), another relates to incentive schemes and how they support production that correlates with unhealthy diets, a third highlights the proven potential of healthier diets and reduced overall environmental impacts.

Résumé

Les systèmes agroalimentaires sont d'une importance capitale pour nos sociétés, car ils fournissent de la nourriture et nombre d'autres services tels que des emplois dans les zones rurales ou des paysages à valeur récréative. Les systèmes agroalimentaires mondiaux ont cependant aussi d'importants effets environnementaux, sociaux et économiques : ils concourent à la perte de biodiversité, au changement climatique, à la pénurie d'eau, à la précarité des conditions de travail et à de mauvaises habitudes alimentaires. Vu l'ampleur considérable de ces effets négatifs, il est essentiel de soutenir la transformation des systèmes agroalimentaires pour les réduire significativement.

Pour aller dans ce sens, il peut être utile de recourir à la comptabilisation du coût complet, c'est-à-dire à l'évaluation des coûts cachés du système agroalimentaire. Par coûts cachés, on entend les coûts qui, bien que résultant de décisions en matière de production et de consommation, ne sont pas comptabilisés au moment où sont prises ces décisions. Ces coûts sont supportés par des tiers ou par la société dans son ensemble ou ne surviennent que plus tard (p. ex., les coûts du changement climatique non comptabilisés au moment de décisions de gestion agricole ou de consommation entraînant des émissions de gaz à effet de serre [GES]). La comptabilisation du coût complet permet donc de chiffrer les effets négatifs susmentionnés. Elle contribue à sensibiliser le public en établissant un lien entre ces effets et le discours économique de prospérité et de génération de PIB, ou plutôt de recul de la prospérité et du PIB quand ces effets sont en l'occurrence négatifs.

L'édition 2023 du rapport « La situation mondiale de l'alimentation et de l'agriculture » (ci-après SMAA 2023) de l'Organisation des Nations Unies pour l'alimentation et l'agriculture (FAO) est consacrée aux coûts cachés des systèmes agroalimentaires à l'échelle mondiale, sur la base d'estimations de ces coûts au niveau national pour un certain nombre de catégories, lorsque des données comparables entre tous les pays étaient disponibles. Pour examiner ces coûts, chaque système alimentaire est considéré selon les activités prenant place à l'intérieur d'un territoire. Autrement dit, les limites sont les frontières politiques : les coûts cachés du système agroalimentaire dans un pays sont relevés en incluant les effets de toutes les étapes, de la production intérieure à la consommation (même si les effets sont générés à l'étranger, p. ex. s'ils sont dus à des émissions de GES ou au ruissellement d'azote dans des cours d'eaux situés hors des frontières nationales), mais sans inclure les coûts cachés inhérents aux denrées alimentaires, aux aliments pour animaux, aux engrais et aux autres intrants qui sont importés.

La présente étude de cas précise les estimations du SMAA 2023 pour la Suisse et les complète par des thématiques non abordées dans le SMAA 2023, afin d'identifier les défis les plus pressants et les opportunités du système agroalimentaire suisse en termes d'externalités et de recommandations de points d'ancrage potentiels pour sa transformation durable.

L'évaluation des résultats du SMAA 2023 a montré que pour la Suisse, les estimations concernant les catégories couvertes dans le SMAA 2023 peuvent être largement reprises sans être précisées, sauf en ce qui concerne les émissions de GES. En effet, sur la base des

études scientifiques les plus récentes, la Suisse utilise une valeur six fois plus élevée pour les coûts sociaux des GES, ce qui aboutit, après application d'une marge de sécurité prudente tenant compte des incertitudes méthodologiques, à des coûts des émissions de GES trois fois plus élevés.

Outre la vérification et la précision des valeurs pour les catégories couvertes par les estimations du SMAA 2023, il est nécessaire d'ajouter des catégories qui en sont absentes. En font partie en premier chef les coûts cachés des pertes de biodiversité, qui s'élèvent à environ 7,5 milliards de francs, soit près d'un tiers de l'estimation initiale. Par ailleurs, les coûts de santé relevés dans le SMAA 2023 ne comprennent que les coûts des maladies non transmissibles dues à de mauvaises habitudes alimentaires, à l'exclusion des coûts de traitement directs et des coûts immatériels liés à la souffrance et à la baisse de la qualité de vie, qui s'élèvent respectivement à 8 et 9 milliards de francs (la comptabilisation des coûts de traitement directs au titre des coûts cachés est particulièrement contestée).

Il est important de noter que certaines de ces estimations peuvent se trouver comptabilisées deux fois, par exemple les coûts supplémentaires liés à la biodiversité peuvent figurer déjà parmi les coûts relevés initialement, dus aux émissions d'azote et à l'utilisation des sols. La part des coûts susceptibles d'être comptabilisés deux fois est toutefois bien inférieure aux coûts des pertes de biodiversité nouvellement ajoutés et n'est donc pas considérée comme un problème majeur. De plus, nous avons généralement adopté une approche prudente, en utilisant des estimations plus basses lorsque les incertitudes sont particulièrement grandes, comme pour le changement d'affectation des terres, pour lequel nous utilisons l'estimation initiale du SMAA 2023, quand bien même il serait justifié de prendre en compte des coûts beaucoup plus élevés. Cependant, cette dernière option donnerait aussi plus de poids à la question de la double comptabilisation, ce que l'utilisation de l'estimation originale, plus basse, permet d'éviter.

Les estimations montrent que les coûts cachés totaux du système agroalimentaire suisse, y compris ces coûts supplémentaires, s'élevaient à environ 32 milliards de francs en 2020 (alors que l'estimation initiale du SMAA 2023 sans ces coûts supplémentaires était d'environ 21 milliards de francs pour cette même année). Les conséquences d'une mauvaise alimentation s'élèvent à 17 milliards de francs, celles des pertes de biodiversité à 7,5 milliards de francs, tandis que les conséquences des émissions de GES et des émissions d'azote sont de l'ordre de respectivement 3,1 et 2,9 milliards de francs. Le tableau ci-dessous récapitule ces résultats.

Par souci d'exhaustivité, le tableau indique aussi les coûts cachés liés aux importations de denrées alimentaires, d'aliments pour animaux et d'autres intrants agricoles. En complément à ce tableau, il convient d'analyser les coûts cachés potentiels liés aux subventions biaisées, à la protection douanière et à d'autres dispositifs d'incitation. Ceux-ci sont particulièrement controversés, très difficiles à quantifier et ne sont donc pas représentés ici.

Catégorie	Valeur SMAA 2023 (en milliards de francs[2])	Valeur précisée / complétée (en milliards de francs)	Différence de coût entre le SMAA 2023 et la valeur précisée
Une saisie « - » signifie que cette valeur n'a pas été estimée parce qu'elle est déjà couverte par d'autres catégories, qu'elle est négligeable ou que les données font défaut ; pour des explications détaillées, voir les sections correspondantes du chapitre 6 ; le lecteur y trouvera, dans la section 6.4.1, une version détaillée du présent tableau et des notes explicatives.			
Précisions			
Santé - estimation de base	17,1	17,1	0
Santé - coûts additionnels	-	8 (coûts de santé directs) 9 (coûts de santé immatériels)	8 9
Émissions de GES	0,9	3,1	2,2
Émissions d'azote	2,9	2,9	0
Utilisation de l'eau	0,0013	0,0013	0
Pollution de l'eau	-	-	-
Pauvreté	0	0	0
Sous-alimentation / malnutrition	0	0,57	0,57
Changement d'affectation des terres	0,22	0,22	0
Compléments			
Phosphore	-	-	-
Santé des sols	-	0,17	0,17
Biodiversité	-	7,5	7,5
Utilisation de pesticides	-	-	-
Résistance aux antimicrobiens	-	0,15	0,15
Bien-être des animaux	-	0,11	0,11
Valeurs additionnées			
Total SMAA 2023	**21,1**		

[2] Les valeurs sont exprimées en milliards de francs ; pour obtenir les valeurs PPA en dollars américains de 2020, il faut les diviser par le facteur de conversion PPA approprié de 1,105 (Banque mondiale, 2024).

Total précisions et compléments		**31,8** (**48,8** si l'on inclut les coûts de santé supplémentaires)	
Différence totale entre les précisions / compléments et le SMAA 2023			**10,7** (**27,7** si l'on inclut les coûts de santé supplémentaires)
Importations (déclarées comme catégorie distincte en raison de limites de système différentes de celles utilisées pour les autres catégories)			
Importations	-	6,7	6,7

Les coûts élevés découlant d'une mauvaise alimentation s'expliquent en grande partie par la productivité élevée par habitant en Suisse, car les estimations sont basées sur les pertes de productivité dues aux maladies non transmissibles résultant d'une mauvaise alimentation (celle-ci entraîne une augmentation des maladies non transmissibles telles que les maladies cardiovasculaires ou le diabète ; il en résulte une augmentation du nombre de jours de congé maladie des employés et une diminution correspondante de leur productivité, ce qui se traduit par des pertes élevées de PIB et donc par des coûts cachés élevés, compte tenu de la productivité élevée de la main-d'œuvre en Suisse).

De manière générale, les coûts cachés dans les catégories autres que la santé sont beaucoup plus faibles. Ces estimations inférieures ne sont toutefois pas automatiquement synonymes d'une importance moindre. Les pertes de biodiversité, les émissions d'azote et les émissions de GES connaissent également des valeurs significatives. Quant aux valeurs relativement faibles concernant l'utilisation de l'eau, la pénurie d'eau ou les résistances antimicrobiennes, par exemple, elles tendent à montrer que si le problème n'est pas encore aigu, les coûts de ces catégories pourraient augmenter. Il importe donc d'observer attentivement l'évolution des catégories aujourd'hui moins importantes pour éviter qu'elles ne deviennent un problème.

Une fois les estimations des coûts cachés disponibles, la tâche principale consistait à identifier les points d'ancrage pour agir, l'objectif n'étant alors pas de suggérer des instruments politiques concrets, mais plutôt de donner une assise solide à un processus ultérieur susceptible de définir de tels instruments. La clé de l'identification des points d'ancrage consiste à attribuer les coûts à leurs auteurs, en identifiant les causes sous-jacentes ainsi que les interdépendances pertinentes. En ce qui concerne les effets de l'alimentation sur la santé, il appartient incontestablement à chaque consommateur ou consommatrice de décider quoi manger, et l'on peut citer les principales mauvaises habitudes alimentaires suivantes : régimes pauvres en céréales complètes, riches en viande, pauvres en légumineuses, riches en viande transformée, riches en sodium, pauvres en fruits, riches en acides gras trans et pauvres en légumes. Cependant, les décisions individuelles en matière de consommation ne sont jamais prises sans contexte : l'environnement alimentaire joue un rôle central. Il est dès lors essentiel de traiter de la responsabilité de l'ensemble du secteur alimentaire, de la publicité et des détaillants, de même que du rôle de la formation, des conseils en diététique et de la gastronomie.

S'agissant de la biodiversité, il est essentiel d'identifier les principaux éléments moteurs dans le contexte d'un changement d'affectation des terres et de la structure du paysage ainsi que de l'utilisation de pesticides et d'engrais. Pour ce qui est des émissions de GES et de l'azote, l'attribution peut être dérivée de l'inventaire des GES et des calculs du bilan azoté. Cela illustre l'importance du secteur de l'élevage pour l'utilisation de l'azote, tout en soulignant le rôle du nombre élevé de têtes de bétail nourries avec des aliments importés et les modes de culture impliquant de grandes surfaces cultivées en céréales fourragères et en maïs fourrager. Cette différenciation et cette attribution sont essentielles quand il s'agit d'aborder la question des coûts cachés des importations et du gaspillage alimentaire, où certaines catégories de produits peuvent dominer dans certaines catégories de coûts.

Il est important de noter que l'auteur des coûts n'est pas nécessairement le décideur à proprement parler. Imaginons, par exemple, que des pesticides soient utilisés dans la production de pommes pour garantir le respect de certains critères de qualité visuelle imposés par les détaillants. L'agriculteur qui applique les pesticides est alors clairement l'auteur des coûts, mais ce sont les exigences des détaillants et les attentes des consommateurs en matière de qualité visuelle qui sont à l'origine de sa décision d'appliquer ces pesticides. Travailler sur ce second volet aurait un effet de levier plus important que la seule focalisation sur les applications de pesticides.

Tous ces points doivent être évalués dans un contexte d'interdépendances complexes. Il est important d'en rendre compte pour exploiter les synergies potentielles entre les différents thèmes et éviter, dans la mesure du possible, les compromis. Pour ne citer que trois exemples, une interdépendance clé existe entre différents aspects (p. ex., cheptel important, coûts élevés pour la biodiversité, aspects sanitaires des émissions d'ammoniac) tous liés aux niveaux élevés d'utilisation de l'azote qui prévalent dans l'agriculture suisse. Une autre concerne les systèmes d'incitation et la manière dont ceux-ci soutiennent la production qui est corrélée avec de mauvaises habitudes alimentaires, et une troisième met en évidence le potentiel avéré de régimes alimentaires plus sains et d'impacts environnementaux globaux réduits.

Zusammenfassung

Agrar- und Ernährungssysteme sind ein zentrales Fundament unserer Gesellschaften. Sie dienen der Versorgung mit Nahrungsmitteln und der Erbringung weiterer Dienste. So etwa schaffen sie Arbeitsplätze im ländlichen Raum und Landschaften mit Erholungswert. Die globalen Agrar- und Ernährungssysteme haben aber auch erhebliche Auswirkungen auf Umwelt, Soziales und die Wirtschaft, da sie für den Verlust der Biodiversität, den Klimawandel, die Wasserknappheit, prekäre Arbeitsbedingungen und ungesunde Ernährungsgewohnheiten mitverantwortlich sind. Das Ausmass dieser negativen Auswirkungen ist nicht zu unterschätzen. Daher ist es von zentraler Bedeutung, Wege für eine Transformation der Agrar- und Ernährungssysteme zu erschliessen, um die nachteiligen Auswirkungen deutlich zu reduzieren.

Ein Ansatz dazu ist die Kostenwahrheitsrechnung, d. h. die Schätzung der versteckten Kosten des Agrar- und Ernährungssystems. Als versteckte Kosten gelten die Kosten von Produktions- und Konsumentscheidungen, die nicht in die jeweiligen Entscheidungen einfliessen und anschliessend von Dritten, gesamtgesellschaftlich oder auch erst zu einem späteren Zeitpunkt getragen werden. Ein Beispiel hierfür sind die Kosten der Auswirkungen des Klimawandels, die bei Entscheidungen über die landwirtschaftliche Betriebsführung oder Konsumentscheidungen, die Treibhausgasemissionen (THG-Emissionen) verursachen, unberücksichtigt bleiben. Die Kostenwahrheitsrechnung beziffert die genannten nachteiligen Auswirkungen und setzt diese mit dem ökonomischen Narrativ der sozialen Wohlfahrt und dem BIP-Wachstum oder vielmehr mit Wohlfahrtsverlusten respektive BIP-Verlusten in Beziehung, um Bewusstsein für diese Zusammenhänge zu schaffen.

Der Bericht über den Zustand von Ernährung und Landwirtschaft 2023 (*The State of Food and Agriculture 2023*, kurz «SOFA 2023») der Ernährungs- und Landwirtschaftsorganisation der Vereinten Nationen (FAO) befasst sich mit den versteckten Kosten der Agrar- und Ernährungssysteme weltweit. Er beruht auf Schätzungen dieser Kosten nach Ländern für eine Reihe von Kategorien, in denen weltweit einheitliche Daten zur Verfügung standen. In Bezug auf die Aktivitäten des Ernährungssystems werden territoriale Systemgrenzen definiert. So werden beispielsweise die versteckten Kosten des Agrar- und Ernährungssystems in einem Staat über die Auswirkungen von der Inlandproduktion bis hin zum Konsum berechnet (auch wenn die Auswirkungen im Ausland auftreten, etwa infolge von THG-Emissionen oder Stickstoffauswaschungen in Gewässern über die Landesgrenzen hinaus). Die Kosten importierter Lebens- und Futtermittel, Dünger sowie Betriebs- und Hilfsmittel sind darin jedoch nicht enthalten.

Die vorliegende Fallstudie verfeinert die Schätzungen des SOFA 2023-Berichts für die Schweiz und ergänzt sie um Themen, die nicht Gegenstand des Berichts waren, um so die dringlichsten Herausforderungen und Chancen des Schweizer Agrar- und Ernährungssystems im Hinblick auf externe Effekte und Empfehlungen für potenzielle Ansatzpunkte für eine nachhaltige Transformation des Systems zu identifizieren.

Die Auswertung der Ergebnisse des SOFA 2023-Berichts ergab, dass die Schätzungen für die im Bericht aufgeführten Kategorien für die Schweiz mehrheitlich ohne Verfeinerung herangezogen werden können. Das gilt jedoch nicht für THG-Emissionen. In dieser Kategorie beansprucht die Schweiz, basierend auf den jüngsten wissenschaftlichen Studien, einen um das Sechsfache höheren Wert für die sozialen Kosten, was unter Berücksichtigung einiger konservativer Sicherheitsmargen für methodische Unsicherheiten in etwa dreimal so hohe Kosten für THG-Emissionen zur Folge hat.

Neben der Überprüfung und Verfeinerung der Werte für die im SOFA 2023-Bericht aufgeführten Kategorien bedarf es der Ergänzung um weitere Kategorien, die im Bericht fehlen. An erster Stelle stehen dabei die versteckten Kosten der Biodiversitätsverluste, auf die rund 7,5 Milliarden Schweizer Franken, d. h. fast ein Drittel der ursprünglichen Schätzung, entfallen. Die Gesundheitskosten im SOFA 2023-Bericht tragen darüber hinaus nur den Kosten von nichtübertragbaren Krankheiten infolge ungesunder Ernährung Rechnung, nicht aber den direkten Behandlungskosten oder den immateriellen Kosten, die sich infolge der Erkrankung und der geringeren Lebensqualität ergeben und auf die 8 bzw. 9 Milliarden Schweizer Franken entfallen (wobei es besonders umstritten ist, direkte Behandlungskosten als versteckte Kosten zu erfassen).

Es ist darauf hinzuweisen, dass einige dieser Schätzungen möglicherweise doppelt erfasst werden, z. B. die zusätzlichen Kosten im Zusammenhang mit der Biodiversität, die bereits in den ursprünglich erfassten, durch Stickstoffemissionen und Landnutzung verursachten Kosten enthalten sind. Der Anteil dieser möglicherweise doppelt erfassten Kosten ist jedoch in Bezug auf ihre Grössenordnung unterhalb der im Zusammenhang mit der Biodiversität neu entstandenen Kosten anzusiedeln. Folglich wird dies als nicht allzu grosses Problem eingestuft. Generell wurde überdies ein konservativer Ansatz verfolgt, bei dem dort, wo die Unsicherheiten besonders gross sind, eher tiefere als höhere Schätzungen verwendet wurden, z. B. bei Landnutzungsänderungen, auf die die ursprüngliche Schätzung des SOFA 2023-Berichts Anwendung fand, obwohl wesentlich höhere Kosten angeführt werden könnten. Dies würde das Problem der Doppelerfassungen jedoch verstärken, was durch die Verwendung der ursprünglichen tieferen Schätzung vermieden wird.

Die Schätzungen zeigen, dass die versteckten Kosten des Schweizer Agrar- und Ernährungssystems, einschliesslich dieser zusätzlichen Kosten, im Jahr 2020 gesamthaft bei rund 32 Milliarden Schweizer Franken lagen (während sich die ursprüngliche Schätzung des SOFA 2023-Berichts unter Auslassung dieser zusätzlichen Kosten für 2020 auf rund 21 Milliarden Franken belief). Dabei entfallen 17 Milliarden Schweizer Franken auf die Folgen ungesunder Ernährung, gefolgt von den Auswirkungen der Biodiversitätsverluste (7,5 Mrd. CHF), der Treibhausgasemissionen (rund 3,1 Mrd. CHF) und der Stickstoffemissionen (2,9 Mrd. CHF). Die nachstehende Tabelle fasst diese Ergebnisse zusammen.

Aus Gründen der Vollständigkeit enthält die Tabelle auch die versteckten Kosten des Imports von Lebens- und Futtermitteln sowie anderer landwirtschaftlicher

Betriebsmittel. Zusätzlich zu dieser Tabelle sollten mögliche, mit unausgewogenen Subventionen, Grenzschutz und anderen Anreizsystemen zusammenhängende versteckte Kosten analysiert werden. Diese Kosten werden besonders kontrovers diskutiert, lassen sich nur schwer quantifizieren und sind daher an dieser Stelle nicht aufgeführt.

Kategorie	Wert SOFA 2023 (Mrd. CHF) [3]	Verfeinerter/ ergänzter Wert (Mrd. CHF)	Kostendifferenz zwischen SOFA 2023 und Verfeinerung
Ein Eintrag «-» bedeutet, dass dieser Wert nicht geschätzt wurde, da er bereits in anderen Kategorien erfasst wurde, Daten fehlen oder er vernachlässigbar ist; für ausführliche Erläuterungen siehe entsprechende Abschnitte in Kapitel 6; dort ist in Abschnitt 6.4.1 eine detaillierte Fassung dieser Tabelle mit Erläuterungen zu finden.			
Verfeinerungen			
Gesundheit – grundlegende Schätzung	17,1	17,1	0
Gesundheit – zusätzliche Kosten	-	8 (direkte Gesundheitskosten) 9 (immaterielle Gesundheitskosten)	8 9
THG-Emissionen	0,9	3,1	2,2
Stickstoffemissionen	2,9	2,9	0
Wasserverbrauch	0,0013	0,0013	0
Wasserverschmutzung	-	-	-
Armut	0	0	0
Unterernährung/Mangel-ernährung	0	0,57	0,57
Landnutzungsänderung	0,22	0,22	0
Ergänzungen			
Phosphor	-	-	-
Bodengesundheit	-	0,17	0,17
Biodiversität	-	7,5	7,5
Pestizideinsatz	-	-	-
Antibiotikaresistenz	-	0,15	0,15
Tierwohl	-	0,11	0,11

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[3] Die Werte sind in Milliarden Schweizer Franken (CHF) angegeben; um die KKP-Werte des US-Dollars für 2020 abzuleiten, müssen sie durch den entsprechenden KKP-Umrechnungsfaktor von 1,105 (Weltbank, 2024) geteilt werden.

Summierte Werte			
Total SOFA 2023	**21,1**		
Total Verfeinerungen plus Ergänzungen		**31,8** (**48,8** einschliesslich der zusätzlichen Gesundheitskosten)	
Total Differenz zwischen Verfeinerungen/ Ergänzungen und SOFA 2023			**10,7** (**27,7** einschliesslich der zusätzlichen Gesundheitskosten)
Importe (als eigenständige Kategorie angegeben, da sich die verwendeten Systemgrenzen von denen der anderen Kategorien unterscheiden)			
Importe	-	6,7	6,7

Die hohen Kosten ungesunder Ernährung sind grösstenteils auf die hohe Pro-Kopf-Produktivität in der Schweiz zurückzuführen, da die Schätzungen auf Produktivitätsverlusten infolge nichtübertragbarer, durch ungesunde Ernährung verursachter Krankheiten basieren. Ungesunde Ernährung begünstigt die Zunahme nichtübertragbarer Krankheiten wie Herz-Kreislauf-Erkrankungen oder Diabetes; diese bedingen wiederum mehr krankheitsbedingte Absenzen der Arbeitnehmenden und eine entsprechende Reduktion ihrer Arbeitsproduktivität, was aufgrund der hohen Arbeitsproduktivität in der Schweiz zu hohen BIP-Verlusten und folglich hohen versteckten Kosten führt.

Generell sind die versteckten Kosten in den anderen Kategorien um einiges tiefer als in der Kategorie Gesundheit. Diese tieferen Schätzungen zeugen jedoch nicht automatisch von einer geringeren Bedeutung. So sind die Werte im Zusammenhang mit dem Biodiversitätsverlust, den Stickstoff- und THG-Emissionen ebenfalls signifikant hoch, während die relativ niedrigen Werte für Wassernutzung, Wasserknappheit und Antibiotikaresistenzen vielmehr veranschaulichen, dass das Problem heute noch nicht allzu gross ist, die damit verbundenen Kosten in Zukunft jedoch noch steigen können. Es gilt daher, die derzeit weniger relevanten Kategorien genau zu beobachten, um zu verhindern, dass sie in Zukunft an Bedeutung gewinnen.

Vor dem Hintergrund der verfügbaren Schätzungen der versteckten Kosten gilt es nun, Handlungsansätze zu identifizieren. Ziel dieser Studie war es nicht, konkrete politische Instrumente vorzuschlagen, sondern vielmehr eine solide Grundlage für einen nachgeschalteten Prozess zu schaffen, in dessen Rahmen entsprechende Instrumente erarbeitet werden können. Um Handlungsansätze zu identifizieren, ist es entscheidend, den «Kostenverursachern» die Kosten zuzuweisen und dabei die zugrundeliegenden Faktoren sowie die relevanten Wechselbeziehungen zu bestimmen. Was die Auswirkungen der Ernährung auf die Gesundheit betrifft, liegt es an den

Konsumentinnen und Konsumenten selbst, darüber zu entscheiden, wie sie sich ernähren. Zu den ungesunden Ernährungsgewohnheiten mit den stärksten Auswirkungen zählen eine Ernährung mit wenig Getreidevollkornprodukten, viel Fleisch, wenig Hülsenfrüchten, reich an verarbeiteten Fleischprodukten, einem hohen Natriumgehalt, wenig Obst, einem hohen Anteil von Transfettsäuren und wenig Gemüse. Individuelle Konsumentscheidungen werden jedoch nie in einem luftleeren Raum getroffen und das Lebensmittelumfeld spielt eine zentrale Rolle. Dabei ist es von zentraler Bedeutung, sich mit der Verantwortung des gesamten Lebensmittelsektors, der Werbung und des Detailhandels sowie der Rolle von Bildung, Ernährungsberatung und der Gastronomie auseinanderzusetzen.

In Bezug auf die Biodiversität gilt es, die wesentlichen Triebkräfte im Zusammenhang mit Landnutzungsänderungen und der Landschaftsstruktur sowie dem Einsatz von Pestiziden und Düngern zu identifizieren. Was THG- und Stickstoffemissionen angeht, kann die Zuteilung aus den Berechnungen des THG-Inventars und der Stickstoffbilanz abgeleitet werden. Dies verdeutlicht, welche Bedeutung der Viehwirtschaft in puncto Stickstoffeinsatz zukommt, und veranschaulicht überdies die Rolle des hohen Viehbestands und dessen Fütterung im Hinblick auf importierte Futtermittel und Anbaustrukturen mit grossen Ackerbauflächen, auf denen Futtergetreide und Futtermais angebaut werden. Eine derartige Differenzierung und Zuteilung sind entscheidend, wenn es darum geht, die versteckten Kosten von Importen und Lebensmittelverschwendung zu thematisieren, wo einige Warenkategorien den Grossteil bestimmter Kostenkategorien ausmachen dürften.

Wichtig ist auch hervorzuheben, dass der Kostenverursacher nicht zwingend der Entscheidungsträger ist, auf den es direkt abzuzielen gilt. Man denke nur an den Pestizideinsatz in der Apfelproduktion, der dazu dient, bestimmte visuelle Qualitätskriterien des Detailhandels zu erfüllen. In diesem Fall sind die Landwirtinnen und Landwirte eindeutig die Kostenverursacher, da sie die Pestizide einsetzen. Die zugrundeliegenden Treiber sind jedoch die Anforderungen des Detailhandels und die Erwartungshaltung der Konsumentinnen und Konsumenten an visuelle Qualitätskriterien. Hier den Hebel anzusetzen wäre weitaus wirksamer als ausschliesslich auf die Pflanzenschutzanwendungen zu fokussieren, ohne diesen zugrundeliegenden Treiber anzugehen.

All dies ist in einem Kontext komplexer Wechselbeziehungen zu bewerten. Ihnen ist Rechnung zu tragen, um auf möglichen Synergien zwischen verschiedenen Themen aufbauen und Kompromisse, sofern möglich, vermeiden zu können. Um nur drei Beispiele zu nennen: Eine zentrale Wechselbeziehung besteht zwischen verschiedenen Aspekten, die über das in der Schweizer Landwirtschaft vorherrschende hohe Niveau des Stickstoffeinsatzes verbunden sind (z. B. hohe Viehbestände, hohe Biodiversitätskosten, mit den Ammoniakemissionen zusammenhängende Gesundheitsaspekte). Eine zweite bezieht sich auf Anreizsysteme und wie sie eine Produktion fördern, die mit einer ungesunden Ernährungsweise zusammenhängt. Eine dritte wiederum betrifft das nachgewiesene Potenzial gesünderer Ernährungsweisen und einer insgesamt geringeren Umweltbelastung.

Abbreviations

DALY	Disability adjusted life year
GDP	Gross domestic product
GHG	Greenhouse gas
PPP	Purchasing power parity
SOFA	State of food and agriculture (report)
TCA	True cost accounting

Glossary

The following terms are copied from the State of Food and Agriculture SOFA 2023 report (FAO, 2023) and thus exactly report the definitions used there. After those, we add some definitions of additional terms not used in SOFA 2023, as needed. For some further discussion and for examples of some of these terms, please refer to section 3.

Terms from the SOFA 2023 report and other FAO sources[4]:

- "**Agrifood systems**. Cover the journey of food from farm to table – including when it is grown, fished, harvested, processed, packaged, transported, distributed, traded, bought, prepared, eaten and disposed of. They also encompass non-food products that constitute livelihoods and all of the people, as well as the activities, investments and choices, that play a part in getting us these food and agricultural products. In the FAO Constitution, the term "agriculture" and its derivatives include fisheries, marine products, forestry, and primary forestry products." [5]
- "**Capital**. The economic framing of the various stocks in which each type of capital embodies future streams of benefits that contribute to human well-being (see also "human capital", "natural capital", "produced capital", "social capital" and "stock")."
- "**Capital change**. The net change in quantity and quality of capital stock."
- "**External cost**. A cost incurred by individuals or a community as a result of an economic transaction in which they are not directly involved. The difference between private costs and the total cost to society of a product, service or activity is called an external cost." We emphasize that the "total costs to society" here refers to those due to market failures only, cf. also the definition of "hidden cost" below; examples of market failures are "externalities" (cf. the following definition), but also monopoles or information asymmetries.

[4] These other sources are indicated specifically for each entry.

[5] Glossary (fao.org)

In the context of the studies on external costs of traffic in Switzerland (Ecoplan/Infras, 2014; Infras & ecoplan, 2019), external costs are defined somewhat differently as describing all costs that are NOT borne by the cost producers. "**Internal costs**" are then defined as the costs borne by cost producers – covering material and immaterial costs, which thus also cover part of the hidden costs as understood in the SOFA report. The total of these external and internal costs are then termed "**social costs**" in these studies.

- **Externality**. "A positive or negative consequence of an economic activity or transaction that affects other parties without this being reflected in the price of the goods or services transacted." (thus: **positive externality** and **negative externality**). The externality thus can be physical (e.g. GHG emissions), while external costs are the related monetarized value.
- **Health**. [Hidden costs related to] "Health - as a result of unhealthy dietary patterns that cause a burden of obesity and NCDs and, consequently, productivity losses. Specifically, unhealthy diets low in fruits, vegetables, nuts, whole grains, calcium and protective fats, and high in sodium, sugar-sweetened beverages, saturated fats and processed meat have been associated with preventable morbidity and mortality from neoplasms, cardiovascular disease and type-2 diabetes. A wide range of market, institutional and policy failures […] drive these dietary patterns by making foods of high energy density and minimal nutritional value more available, cheap and convenient." (from Annex 1 of the SOFA 2023 report FAO (2023))
- "**Hidden cost**. Any cost to individuals or society that is not reflected in the market price of a product or service. It refers to external costs (that is, a negative externality) or economic losses triggered by other market, institutional or policy failures." In this, "hidden costs" encompass "external costs", where the latter arise from market failures in the narrower sense of microeconomic externality theory, while the former include any costs that may arise due to other than market failures, i.e. institutional or policy failure (cf. definitions below). It has also to be emphasized that hidden costs are not necessarily "invisible" in the sense that decision makers or society at large would not be aware of them – they are hidden/invisible in the sense that they are not accounted for in decisions.
- "**Human capital**. The knowledge, skills, competencies and attributes embodied in individuals that facilitate the creation of personal, social and economic well-being."
- "**Institutional failure**. When institutions – governments, markets, private property and communal management – fail to provide the necessary framework for development. From a sustainability perspective, it has been defined in terms of the inability of institutions to conserve resources. Institutional failures manifest in a variety of ways, e.g. corruption, ill-defined property rights." (part of them thus lead to market failures, parts cover other aspects of ill-functioning societal organisation).

- "**Market failure**. A situation in which the allocation of goods and services by a free market is not efficient, often leading to a net loss of economic value to society, that is, the full benefits of the use of social resources are not realized. There are many types of market failure, e.g. market power, externality, public good."
- "**Natural capital**. The stock of renewable and non-renewable natural resources that combine to yield a flow of benefits to people."
- "**Policy failure**. When a policy, even if it is successful in some minimal respects, does not fundamentally achieve the goals that proponents set out to achieve. Policy failures are dependent on the policy landscape, whose contours are shaped by fiscal policies, regulations and standards." (both policy and institutional failures are rather vague terms, partly covering or resulting in market failures, partly covering other aspects, and partly coinciding and not being separated clearly; in come contexts, policy failures are also seen as a subset of institutional failures);
- "**Private cost**. Any cost paid by a consumer to purchase a good or by a firm to purchase capital equipment, hire labour or buy materials or other inputs. These costs are included in production and consumption decisions." These are thus costs that are immediately "visible" and thus not hidden to decision makers in the sense of being accounted for in their decisions.
- "**Produced capital**. All manufactured capital, such as buildings, factories, machinery and physical infrastructure (roads, water systems), as well as all financial capital and intellectual capital (technology, software, patents, brands and so on)."
- "**Social capital**. Networks, including institutions, together with shared norms, values and understandings that facilitate cooperation within or among groups."
- "**Social cost**. The decrease in economic value to society from a capital change. It is estimated in monetary terms by an economic valuation of the decrease."
- **SOFA 2023**. The State of Food and Agriculture Report by the Food and Agriculture Organization of the United Nations FAO from 2023.
- "**True cost accounting (TCA)**. A holistic and systemic approach to measuring and valuing the environmental, social, health and economic costs and benefits generated by agrifood systems to facilitate improved decisions by policymakers, businesses, farmers, investors and consumers." Beyond the SOFA 2023 report, we emphasize that the term "True cost" is often deemed problematic, as it suggests an optimal situation (in German, the term "Kostenwahrheit" is often used in this context) that is not given, as usually not all costs can be accounted for completely.

– "**Unhealthy diets.** [Diets] low in fruits, vegetables, nuts, whole grains, calcium and protective fats, and high in sodium, sugar-sweetened beverages, saturated fats and processed meat."[6]

Inspired by these definitions, we add the following on hidden benefits and some other terms:

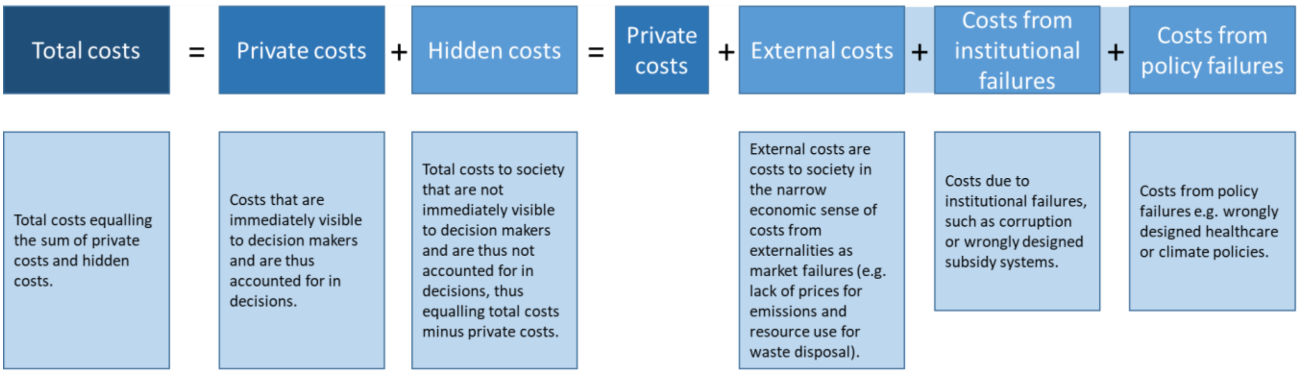
– **Direct costs**. Costs that are directly and clearly linked to some activity, thus often partly coinciding with private costs, but not necessarily. Often also used to capture costs that are very clearly defined, in addition to be directly related to some activity. An example are direct health costs, referring to the treatment costs. For some, direct costs are identical with private costs and indirect costs with hidden costs.

– **Hidden benefit**. Any benefit to individuals or society that is not reflected in the market price (and thus the revenue for the producer) of a product or service. It refers to positive externalities or economic gains triggered by other market, institutional or policy failures (e.g. the benefits due to unpaid care work). Importantly, the various direct payments and other subsidies for farming support are NOT hidden benefits as they are increasing farm income and taken into account in individual production decisions.

– **Immaterial / intangible costs**. The health costs related to individual physical and mental suffering from sickness; often estimated via willingness-to-pay for avoidance of such suffering.

– **Private benefit**. Any revenue received by a producer from selling a good or service. These benefits are included in production and consumption decisions. Consumer and producer surplus (as the difference between the price paid/received and the price at which the consumers would be willing to buy and the producers would be willing to offer the product or service) can be included here as well.

Graphical illustration of some of the key concepts described above:



[6] Annex 1 of the SOFA 2023 report: https://openknowledge.fao.org/server/api/core/bitstreams/8a80e31b-3c41-419d-a11d-0b62e4b2528a/content/state-of-food-and-agriculture-2023/annexes-1.html

Acknowledgments

The authors would like to thank the members of the project team at the Federal Office of Agriculture FOAG (Anna Beerli, Saskia Sanders) and FAO (Ahmad Sadiddin, Aslihan Arslan, Andrea Cattaneo, Sara Vaz, Alejandra Jimenez Tabares, Theresa McMenomy, Elisa Ranuzzi, Miguel Benitez Humanes) as well as the members of the monitoring group and further experts (Patrik Aebi, Ruth Badertscher, Dominique Barjolle, Gino Baudry, Murielle Bochud, Michael Bock, Petyo Bonev, Jean Busché, David Comis, Daniel Erdin, Anina Gilgen, Lena Gubler, Andreas Hauser, Vinzenz Jung, Alwin Kopse, Simon Lanz, Joséphine Leuba, Steven Lord, Joachim Marti, Reto Meier, Thomas Meier, Andrea Poffet, Fabian Riesen, Isabelle Schluep, Martjin Sonnevelt, Urs Stalder) for their time and for all their very helpful comments and suggestions we received in written form as comments to earlier draft versions of this report as well as during the repeated monitoring group meetings and during individual exchange on specific topics. Any errors remain the responsibility of the authors.

Imprint

Report commissioned by the Swiss Federal Office of Agriculture FOAG and the Food and Agriculture Organization of the United Nations FAO.

Suggested Citation: De Luca, Kevin and Muller, Adrian, 2025: Hidden costs of the Swiss Agrifood System - Case Study for the State of Food and Agriculture Report SOFA 2024. Report commissioned by the Swiss Federal Office for Agriculture FOAG and the Food and Agriculture Organization of the United Nations FAO. Research Institute of Organic Agriculture FiBL, Frick

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1. Introduction

The agrifood system produces essential goods. Foremost food for people, but also a number of public goods like landscapes of recreational value. However, the agrifood system also has adverse impacts and causes significant costs, e.g. related to biodiversity loss or unhealthy diets. Some of these costs are direct, visible and taken into account in the decisions by the market participants, while others are hidden and not be taken into account in production and consumption decisions and are thus borne by society. This leads to distorted outcomes compared to the social optimum. Such costs are often termed "hidden costs".

The FAO report "The State of Food and Agriculture 2023 - Revealing the true cost of food to transform agrifood systems" (Lord, 2023a) addresses these hidden costs. The ultimate aim of this is to contribute to food system transformation, as the report's title states. Such is direly needed, given the adverse impacts of the agrifood system, such as nutrient runoff to waterbodies, ammonia and greenhouse gas emissions, soil fertility and biodiversity loss, or ecotoxicity related to pesticide use, making such transformation central to reach the Sustainable Development Goals and the goals of the Paris Agreement. Besides these most-debated impact categories, many others are relevant. These often go less if not even fully un-noticed by many stakeholders. Examples are adverse consequences of antibiotics and hormone use, increased water treatment costs, reduced health due to unhealthy diets and related non-communicable diseases, or the adverse health effects of environmental impacts such as air pollution from ammonia. Furthermore, inequality and injustice due to low wages and exploitative employment relations of agricultural workers, or also animal welfare issues need to be named. Some of these impacts set a chain of further effects in motion, such as reduced productivity or increased susceptibility to communicable diseases as a consequence of reduced health.

True cost accounting ("Kostenwahrheit" in German) plays an important role in the debates on food system transformation also in Switzerland. The climate strategy for food and agriculture from 2023 (BLW/BAFU/BLV, 2023) of three federal offices under the lead of the federal office for agriculture, for example, formulates approaching true cost accounting (TCA) for food as one of their measures for implementation (K-07). Similarly, the federal government names TCA as a central area for action in its report on the future orientation of agricultural policy 2030, and the parliament has subsequently requested suggestions for concrete implementation of this from the federal council (Postulat 22.4251; Bundesrat, 2022; Giacometti, 2022).

When talking about agrifood system transformation in a high-income country such as Switzerland, a number of central strategies come into mind: such as shifts to healthier diets, in particular with reduced sugar and increased fruit, vegetable, pulses, nuts and whole grain product consumption (FCN, 2019); shifts to reduced use of mineral fertilizers, imported feed and cropland use for feed, with correspondingly reduced livestock numbers and consumption of livestock products; increased nutrient use efficiency on croplands; reduced food waste and loss. Related to this are the principles of sustainable intensification with a focus on productivity and efficiency increases, the principles of circular food systems, where nutrient cycles are closed as much as possible, nutrient losses are minimized and external input use is reduced, as well as "one health"-principles, aiming "to sustainably balance and optimize the health of people, animals and ecosystems" (FAO, 2024b).

How to embark on a path of agrifood system transformation is however unclear and past developments – or lack of such – indicate that transformation has not yet begun or is very slow. For Switzerland, this can be seen in the inability to reach the environmental goals for agriculture as formulated in 2008 (FOEN, 2008), where only slow progress is visible (e.g. on ammonia emissions reduction) (FOEN, 2016), or the prevailing high food waste levels and an only slow reduction of meat and other animal source food consumption (FOEN, 2023a; FSO, 2024). This contrasts with the fundamental changes that are called for by a number of strategies for sustainable food system futures, such as formulated in the Climate Strategy for Food and Agriculture 2050 from Switzerland (based on the long term climate strategies of Switzerland), where production-related greenhouse gas emissions are envisaged to be reduced by 40 percent compared to 1990 and per capita emissions from food consumption by two thirds compared to 2020 (BLW/BAFU/BLV, 2023).

Against this background, information on hidden costs helps to better assess the suggestions for transformative action. Various groups make such suggestions, spanning a broad range from more organic agriculture to GMOs, from increased efficiency and precision farming to focusing on circularity principles with reduced livestock numbers, from reducing product-based footprints to changing diets. The corresponding debates on these partly incompatible suggestions are often not constructive. Addressing hidden costs takes a step back and does not directly start with measures but first begs the question where these costs arise and what the causes are, to only then identify which measures may be most adequate to reduce them. Most promising measures can then be identified in relation to

- where biggest costs arise,
- what the drivers and interdependencies are,
- how effective actions to reduce these costs may be, and
- which difficulties the implementation of these actions may face.

For designing such implementation, two additional central questions need to be formulated, namely

- Who bears the hidden costs and would thus benefit from a reduction of those, and is the cost bearer the same actor as the cost producer? In relation to GHG emissions, for example, costs are borne by future generations, gains from any investment today in reducing those will thus also manifest in the future only.
- What drives these costs? I.e. addressing in which context they arise, instead of focusing on current behaviour, which is close to blaming certain groups for these costs, but also on the factors and incentives that shape this behaviour.

Importantly, measures for reducing hidden costs may not necessarily be implemented where the cost occur, as e.g. a GHG-tax that can be levied at the level of fossil fuel importers rather than at the level of individual consumers using fossil fuels.

The State of Food and Agriculture Report SOFA 2023 of the FAO contributes to the identification of hidden costs by offering globally consistent estimates of country-level hidden costs of the agrifood system. Globally, these costs amount to about 13 trillion US dollars, corresponding to about 10 percent of global GDP. For Switzerland, these are about 17-22 billion US dollars (19-24 billion CHF), equalling 3-4 percent of national GDP in 2020 (Lord, 2023b)[7]. This serves as a starting point for more in-depth analyses of these hidden costs for single countries, which then help to identify potential country-specific transformational actions. The State of Food and Agriculture Report SOFA 2024 focuses on these more in-depth analyses and transformative aspects and thus serves as a companion report to SOFA 2023. Central to this are a number of illustrative case studies, and this report here on Switzerland is one of these. Its aim is thus to make the hidden costs of the Swiss agrifood system visible, quantify their size and identify main challenges, in order to provide an objective basis for policy making.

When addressing hidden costs, it is also important to clearly state that agriculture primarily produces huge benefits for society in the form of food and further public goods. Some of these are at least partly made explicit, as Articles 104 and 104a of the Swiss Federal Constitution states that the Confederation shall ensure that agriculture makes a significant contribution to self-sufficiency, the preservation of natural resources, decentralized settlements and the cultural landscape. Part of these benefits are hidden in the sense of our definitions, i.e. currently not being considered in market actors' decisions, while others are not hidden, as their provision is supported e.g. in the form of subsidies. Given the relevance of these benefits, we address them in more detail in section 4.

This report uses a number of specific terms, such as "hidden costs", "external costs", "internal costs" and others. We present the definitions we use for these and related terms in the glossary at the beginning of this report. These definitions and the use of these concepts turned out to be quite controversial, hence we provide some further discussion and some examples of the different terms in section 3.

After this introduction, the structure of this report is as follows. The next section shortly presents the aims of this case study report on TCA for the Swiss agrifood system, section 3 presents some considerations on the concepts used and section 4 addresses hidden benefits. Section 5 presents the cost estimates from the SOFA 2023 report for Switzerland. Section 6 addresses how they may be refined and amended for Switzerland and compares them to other studies on the hidden costs of the agrifood sector of Switzerland

[7] The original numbers in this publication are 20-25 billion US$ (22-28 billion CHF), here we already corrected those for the updated health cost estimates in SOFA 2024 that amount to about 15.5 billion US$ (17 billion CHF) instead of 18.8 billion (21 billion CHF), cf. section 6.2.1. Conversion between US$ PPP 2020 and CHF is done by means of the PPP conversion factor of 1.105 for CHF in 2020 (World Bank, 2024).

and also globally, and to some similar studies for other countries. Section 7 identifies entry points for food system transformation pathways based on hidden cost estimates and section 8 concludes. A first appendix provides a description of how the process for compilation of this report has been organised, in particular showing the broad expert involvement achieved and a second appendix provides a list of some further contacts, data and ongoing projects.

2. Aim of the case study report

By adopting the framework of hidden costs, the discussion is explicitly framed within an economic context. This reflects the choice of a consistent framework that helps to identify a number of important system failures leading to economically inefficient decisions where market prices do not reflect the true costs of goods. How the hidden costs are then reduced is a separate discussion. Furthermore, it offers a common metric to provide some information on how the different costs compare to each other. Thereby, the uncertainties in cost estimates and also potential disagreement on the adequacy of a certain metric chosen for a specific cost estimate need to be acknowledged (e.g. the choice of productivity losses for assessing the costs of reduced health due to environmental impacts and unhealthy diets). Despite these uncertainties, a TCA approach allows to identify the magnitude and the producers and bearers of hidden costs. This information serves to identify the possible crucial leverage points for transformation.

The goal of this case study report based on the SOFA 2023 results on the hidden costs of the Swiss agrifood system (Lord, 2023b) can be formulated as follows:

- It should provide suggestions on how the SOFA 2023 approach and results can be used to identify entry points for policy measures for agrifood system transformation pathways, for the case of Switzerland. Thereby, it should provide a scientific basis for further (political) action without already developing suggestions for such (i.e. focusing on entry points for actions and not suggesting and discussing concrete policy instruments for implementation).
- It should thus first in particular address,
    - to what degree the cost estimates from SOFA 2023 make sense for Switzerland,
    - where potential refinements and amendments are needed,
    - how these potential updates change the values of the estimates,
    - and where knowledge gaps prevail and need to be closed.
- It should then provide suggestions on
    - where in the Swiss agrifood system cost-reducing action may be most effective, and
    - who needs to be addressed to implement them.

These numbers are developed independently of any discussion on concrete policy measures with the aim to provide a sound and widely accepted basis for the political debate on the measures to be taken.

Finally, it has to be kept in mind that TCA is a very complex endeavour and would ultimately require a full economic equilibrium model, coupled to biophysical agronomic and ecosystem models, climate and air pollution models as well as metabolic health models. Any realistic implementation of such is prone to many inconsistencies and data, knowledge and modelling gaps, given the broad topical coverage and the many disciplines involved. Cost data to price the various impacts are in many cases not available and benefit transfer (cf. section 5.1) for utilizing cost estimates from elsewhere (e.g. from other countries, other sectors) is required, leading to considerable additional uncertainties and inconsistencies. SOFA 2023 adopted an approach as consistent as possible on global level, at the costs of excluding many topics where no global data was available.

In this context, it is important to identify which gaps need to be closed when attempting a more detailed country specific assessment, and with which effort. Given the complexity of the task, one should aim at identifying which cost categories are of high, medium or low importance, and to ensure that none of the important categories are neglected. Thus, the focus may be on ensuring coverage of all important aspects to a certain extent, including most relevant interdependencies, rather than on detailed refinement in a context of large uncertainties and knowledge gaps. This is all the more true because, at a certain level of detail, endless cause-effect chains would need to be assessed, e.g. relating to the productivity losses of an increased number of doctors that are required to treat the large number of people with dietary health problems, who could otherwise have been trained on other, more productive jobs. By its very structure, an economic equilibrium model would account for all these effects implicitly, if set up correctly and completely, which, as said, is not possible.

Changes and amendments to the SOFA 2023 assessment should be undertaken if they are relevant for meeting the goals formulated above. Furthermore, the focus is on country specific analysis and less on a comparative analysis between different countries. In consequence, changes in the concepts, methodology or data used by SOFA that may be warranted for better country specific analysis are unproblematic, as the focus is not on inter-country or global comparability and consistency of results, but rather on supporting country-specific food system transformation processes. Clearly, full transparency and traceability of changes needs to be ensured. In the end, country-specific analysis should allow to identify the most relevant cost categories, to agree on the magnitude of the costs involved, and to identify the main entry points for action.

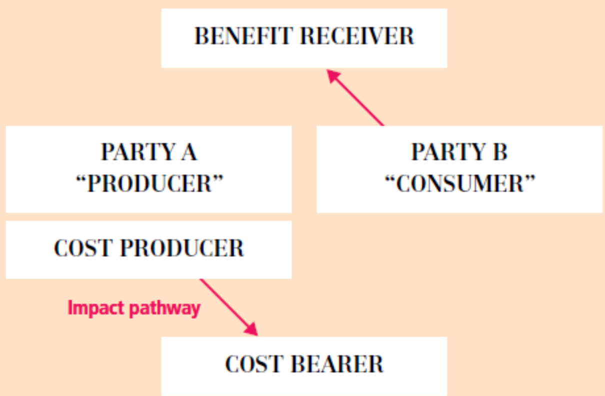
We emphasize already here that the numbers presented in the refinements and complements in section 6 and also in the presentation of the SOFA 2023 estimates in section 5 come with large uncertainties and we work with rounded numbers – hence calculations may show some rounding errors in the digits.

3. Concepts and terms used

As a preamble to this section, we state that the views on what to include and what not to include in the valuation of hidden or external costs – and how to name them – may legitimately differ, as will become clear below.

The concepts and terms used for this study were discussed controversially in the project and monitoring group. The SOFA 2023 report uses the term "hidden costs" for "any cost to individuals or society that is not reflected in the market price of a product or service", and "external costs" being "cost incurred by individuals or a community as a result of an economic transaction in which they are not directly involved" (FAO, 2023). From various contexts in Switzerland, somewhat different terms are in focus. For the costs of traffic, it is "private costs", i.e. the costs that are directly incurred by those who cause them and thus influence their behaviour, and "external costs", i.e. costs that are not incurred by those who cause them but by society at large or future generations, and thus do not influence the behaviour of those causing them (ARE, 2023a). Some members of the monitoring group to this case study project also suggested to refer to direct and indirect costs for these two cost categories "internal/non-hidden" and "external/hidden" costs.

Given the aim of the SOFA 2023 hidden cost assessment and this case study, the central characteristics of costs in general are indeed whether or not they are accounted for by decision makers in their decisions, or, framed with a different focus, whether or not cost producers and cost bearers are identical, also in a temporal dimension (e.g. the case of current generations causing costs for future generations). For illustration, see Figure 1.



Notes: A cost bearer may be a third party or a party to the transaction at a later time. The benefit receiver here receives additional benefits due to the cost bearing of the cost bearer. Party A, party B or both may be cost producers or benefit producers due to their activities. The classical example is external costs of pollution in the production of goods, where damages caused by pollution are not included in the costs of production for A. The buyer B purchases at a lower price, enabling lower production costs and higher profit from the sale of B's own goods, which increases returns to investors, among benefit receivers. The cost bearer of pollution from A has paid for free benefits to the investor of B. The complex path from the production of pollution such as GHGs to the bearing of costs by economic actors in a future economy is one of the challenges in estimating agrifood systems external costs and the costs of market failures.

Figure 1: Imperfect market situation where cost bearers are separate from cost producer and benefit receiver, for example producers and consumers (copied from figure 1 in the methodological background paper to SOFA 2023 (Lord, 2023a))

Classical examples of such external costs in a narrower microeconomic sense are the costs related to greenhouse gas emissions (e.g. emitted by a car) that are largely borne by society and not by the cost producer (e.g. car driver). For those costs, assessment and monetarization is also conceptually rather straightforward (Bertschmann et al., 2020).

The quantification of the costs that are not considered by the cost producers in their decisions is an important information for policy makers in order to then develop measures to change this situation, i.e. to contribute to agrifood system transformations. In this respect, the concept of TCA helps to increase transparency and to identify central drivers of hidden costs. It thus serves to identify central entry points for such transformation and where action may be most needed. TCA does however not tell who should/has to take action and what measures might be implemented, e.g. to reduce or compensate for hidden costs. The design and implementation of concrete measures has to account for the specific context. In complex situations of power inequalities, for example, between farmers and retailers, it is not clear how much freedom of choice the cost producer (e.g. a farmer applying pesticides) has with respect to the pressure exerted by other market players (e.g. regarding requirements for spotless clean vegetables), and which consequences this may have for the design of policies to reduce costs.

When talking about hidden costs, one should also touch on opportunity costs. Opportunity costs arise from the fact that a certain resource, e.g. a certain quantity of water or land cannot be used for more than one activity. They then illustrate how costly it is in terms of foregone revenues to decide for one action instead of another. Opportunity costs thus arise from the necessity to make choices in the presence of scarcity, and they are not external costs, if the price for the resource used reflects this scarcity in relation to demand (clearly, external costs due to the use of this resource can arise in addition, but these are not part of the opportunity costs). Similarly, consumer and producer surplus are not hidden costs or benefits, as they are at the core of the market equilibrium. Neither are costs related to insurance solutions in the health care system. Insurance solutions can lead to some biased decisions, as some decision makers may not consider the full potential costs. But it is primarily a risk management instrument that, if designed correctly, can also be priced efficiently for a whole sample of people (if however designed wrongly, hidden costs due to such institutional failures can occur also in such insurance contexts). Additional government expenditure that flows into the health care system is then also seen as an instrument of a solidary or welfare state and is therefore not regarded as an external cost to society.

Further aspects that can be seen as hidden costs due to policy or institutional (albeit not market) failure are aspects such as adverse impacts of very low wages and related inequalities, which may be established in a market equilibrium but perceived as immoral by many. This applies to other aspects that may not be reflected in GDP losses, such as costs related to animal welfare issues and moral unease of societies related to this or the individual costs of mental and physical suffering due to diet related noncommunicable diseases that are partly counted as external and partly not (cf. next paragraph).

Hidden costs of unhealthy diets are controversially discussed and less tangible in the context of hidden costs compared to environmental costs. Here, the consumers' dietary decision causes costs for the society in terms of foregone wealth. The forgone wealth derives from productivity losses which in turn derive from poor health based on a poor diet. Due to the high labour productivity in Switzerland, the corresponding costs are very high and dominate the hidden cost estimates in SOFA 2023. Conversely, a healthy and balanced diet leads to healthy and productive workforce and therefore maximal prosperity. Different to these productivity losses from diet-related noncommunicable diseases, direct treatment costs and the partly immaterial individual costs (not related to productivity losses) from reduced quality of life or reduced lifetime due to the diet-related noncommunicable diseases are not accounted for as external costs in SOFA 2023 (Lord, 2023b).

The rationale for excluding direct costs related to productivity losses due to unhealthy diets is that the direct treatment costs are accounted for in a market context and therefore not hidden (health care system – acknowledging shortfalls that may counteract this, cf. above) and the immaterial/intangible costs from individual suffering and reduced quality of life due to poor health conditions (i.e. the costs not related to reduced labour productivity as employees) are purely individual, where cost producer and bearer are identical and no GDP losses result. A rationale for considering these direct costs as hidden costs would be, that they are not fully accounted for in individual consumption decisions and neither in business decisions. The crucial question here is whether the consumption decisions of individuals are due to the individual preferences of the consumers or whether external factors dominate the decision-making process (e.g. advertising, lobbying, nutritional environment, product prices). If external factors dominate, then the associated direct costs need to be considered as hidden costs, as the businesses deciding on action that influence individual consumption do not account for the associated health costs to individuals.

Related to these questions on which cost components to include or not in a hidden costs estimate is the suggestion to differentiate exactly, whether cost producers harm others or themselves. From the point of micro-economic externality theory, this is not so relevant, as long as the cost producer does not account for the external costs in his or her decisions – be it costs incurred by him- or herself or by others. Questions then may rather arise as to why a cost producer does not take into account the costs caused by him- or herself. But this is less of conceptual economic relevance than with regard to psychological aspects and the design of potential interventions that have to account for such cases. This is clearly relevant in the context of unhealthy diets, where the individual costs and potential remedies are largely known, but individual behaviour to avoid them is largely not adopted. Thereby, it has to be recognized that individual health behaviour is shaped by many different factors also beyond individual preferences or business involvement, including education, income-level, access to healthcare, and socio-cultural aspects.

Another type of costs discussed controversially are the economic costs related to subsidies, border protection and the like, as addressed in detail in Dümmler and Roten (2018). These authors claim that many of these payments are inefficient from a societal point of view, but most of them are clearly not hidden since decision makers do account for them. Subsidies and other support payments, border protection, attractive conditions for investments, etc. clearly have direct effects on costs and prices and thus influence production and consumption decisions, in extreme cases even forcing decisions because there are no alternatives, e.g. border protection leads to supply of higher-priced domestic products only. The main question related to the inefficiency of subsidies and border protection is then rather whether the goals that these instruments are trying to achieve are the goals that society currently really wants to support, and whether the instruments chosen are well designed to achieve these goals, or whether - conversely - they support and promote drivers of hidden costs and thus increase them rather than reduce them. These costs are not hidden but it is legitimate to discuss them in a context of the societal debates on how to use tax money. Given that some of these payments may have adverse effects regarding other societal goals (e.g. regarding a reduction of nitrogen emissions, biodiversity protection, climate protection, public health, etc., cf. e.g. Gubler et al. (2020b)), they have to be taken into account when debating pathways for agrifood system transformation. In the context of the SOFA 2023 and this case study, with its goal to use hidden cost assessments to support such transformation, it is thus justified to discuss these costs related to subsidies and other incentives such as border protection, albeit they are not external costs in the core sense.

Concluding from the above considerations and referring to the aims formulated in chapter 2, we formulate that "generating visibility for cost categories that have tended to be neglected in decision making (referred to as hidden costs)" shall be the guiding principle for refinements and amendments to the SOFA 2023 estimates of hidden costs of the agrifood system. We thus speak of "hidden costs" in the following, generally not differentiating further. This pragmatic goal-oriented approach comes somewhat at the expense of full consistency regarding globally available and comparable data, double counting and coverage of identical categories within identical system boundaries for all indicators (as assured in SOFA 2023), but we think this is warranted given the aims pursued. Thus, we will focus less on the type of costs (internal, external, hidden or not, etc.) to which a given cost may refer to, but rather on where the highest hidden costs arise, the reduction of which may contribute most to the transformation of the agrifood system towards greater sustainability. Due to the context of the specific and concrete topical discussions in subsections 6.2 and 6.3 this should also not lead to confusion. For general reference, we copy here the figure from the glossary, presenting some graphical representation of the core concepts used (Figure 2):

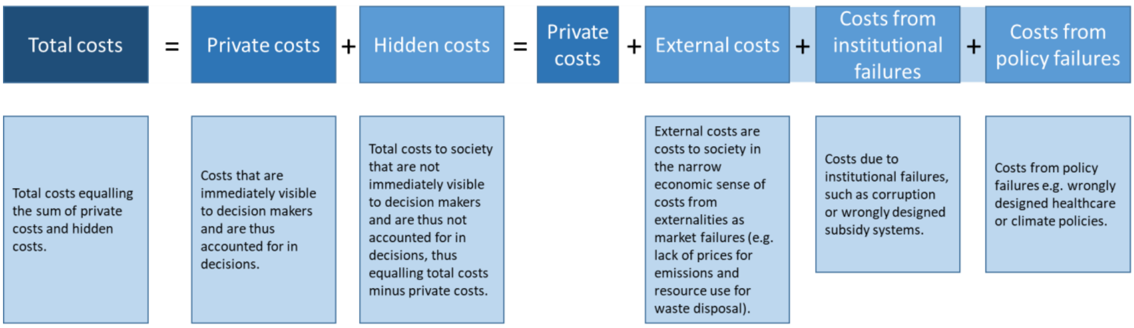


Figure 2: The various core concepts used (copied from the glossary)

4. Hidden and non-hidden benefits from agriculture

To put hidden costs in some relation to what is produced in agriculture and to what other services the agrifood system may provide, these costs can be put in relation to the (hidden) benefits from the agrifood systems. The SOFA 2023 report, however, refrains from doing so explicitly. With hidden costs, the rationale of making them visible and internalising them is to put a price on them so that they are taken into account in decisions and thus reduced. Similarly, if a benefit is hidden in the sense of not being considered in decisions, internalising and making it visible would then result in increasing these benefits, as providing such would result in getting some monetary reward for doing so (e.g. via subsidies for the provision of specific habitats as public goods). The agrifood system clearly generates huge benefits, but most of them are not hidden. This applies for consumer surplus, which is not a hidden benefit but a core aspect of a market equilibrium with heterogeneous producers and consumers, and it also applies to many benefits that are accounted for via direct payments (e.g. for cultural landscapes or for production as a contribution to self-sufficiency: "Versorgungssicherheits- und Landschaftsqualitätsbeiträge"). For these benefits, the cultural and traditional aspects are particularly important: opening and maintaining landscapes and traditional farmers housing, preserving certain biotopes, contributing to the recreation of the population and to the cultural heritage, and to the food culture, etc. can be named here. The profound link between agriculture and culture is strong, and since long time, the Swiss Constitution recognizes the multi-functionality of agriculture.

Clearly, the main focus of the case study is on hidden costs and how policy can act on reducing those. Hidden benefits need thus not be quantified on a similar level of detail as the hidden costs, if at all. Often, quantification would be difficult and only qualitative assessment would be possible. Making them visible in contrast to the hidden costs and highlighting their presence and relevance is however important, also illustrating where which type of hidden benefits plays a role. For some hidden benefits, there may be some quantification possible, e.g. related to landscape value quantification (which benefits are then not hidden anymore, in case such quantification resulted in corresponding supporting payment schemes) and those studies available should be reported, without capturing these benefits systematically or adding much detail. Furthermore, it is important to be aware of the potential danger of diluting the size of the problem captured by hidden costs, if contrasted to hidden benefits and maybe even summed. Such summing is clearly technically possible due to the common monetary metric of all these estimates, but practically not legitimate, as the hidden benefits do not reduce the hidden costs. In this context, it also needs to be highlighted that hidden benefits are not money that can directly be taken and distributed for compensation of hidden costs. In any case, communicating on hidden and non-hidden benefits helps to do justice to what the agrifood system delivers to society, despite the costs it also imposes.

As with hidden costs, where it is important to address who bears them and who benefits from their reduction, with hidden benefits it is important to address who benefits from them. In the case of landscape provision, where the farmers keep mountain landscapes open with their grazing animals, the main beneficiaries are the tourism sector and the state of biodiversity. It is then also important to discuss who pays for this provision, e.g. when direct payments/subsidies are involved for certain management systems, etc.

Finally, reporting hidden benefits of the agrifood system is important to counter such statements as e.g. prominently made in the context of the "Economics of the food system transformation" report (FSEC, 2024), which is based on the same calculations as SOFA 2023: "The economic value of this human suffering and planetary harm is well above 10 trillion US$ a year, more than food systems contribute to global GDP. In short, our food systems are destroying more value than they create." This last sentence definitely does not make much sense, given that without the food system, there would be not many humans left, thus illustrating the absurdity of one-sided cost-benefit-analysis, where the costs encompass all hidden categories, but the benefits cover market transactions only.

In conclusion, it is thus suggested not to quantify the hidden benefits, but rather to mention and highlight these benefits of the agrifood system when addressing its hidden costs, to put all this in context, but not to refer to them for any suggestions for food system transformation pathways, that are mainly related to the hidden cost assessments.

5. Costs covered in SOFA 2023

The hidden cost estimates in the SOFA 2023 report are available on country level. The detailed results for Switzerland are available in the background paper for Switzerland (Lord, 2023b). For this case study report, the central role of TCA estimates is their use in the national process of agrifood system transformation and related debates, policies and interventions. Hence, key topics of national importance as well as scientific relevance influence the selection of potential refinements to the SOFA 2023 estimates rather than a pure assessment of the possibility for refinements wherever more detailed and additional national data is available. Before addressing these refinements with a focus on the Swiss context in section 6, we however present the numbers for Switzerland as stated in SOFA 2023 in this section, as a basis for these further discussions. With this, we also shortly present the methods used.

5.1 Short introduction to the methods used in SOFA 2023

A short, general description of the methods used is provided in Box 6 in the SOFA 2023 report FAO (2023) and for details, we refer to the background paper for Switzerland as well as the general methodological background paper and model documentation to the SOFA 2023 report (Lord, 2020, 2021c, 2021a, 2021b, 2022, 2023b; Lord & Paulus, 2022).

The basic method for estimating hidden costs is to first determine the emissions and other impacts that result in hidden costs, to multiply those quantities with a per unit costs in the base year and in any year in the future in which the costs will arise (which is central, e.g. for GHG emissions, where the impacts and related costs largely materialize in the future), and then to sum these costs over all years up to the time-horizon chosen, e.g. 2100. Unit costs are measured in marginal damage costs, i.e. the costs caused by one additional unit of emissions or impact. For the estimates on both the quantities and the marginal costs, it is central to make clear assumptions on the scenarios about the future development, as e.g. marginal costs of GHG emissions also depend on the emission pathways in the future (the costs of an additional ton of methane or nitrous oxide, for example, are lower in a low-emission scenario than in a high emission scenario, due to potential tipping points in impacts when a certain level of GHG concentrations in the atmosphere is surpassed). For the SOFA 2023 estimates, the business-as-usual pathway as used in the IPCC reports was chosen as a reference development in the future (the so-called SSP2 pathway). A key parameter in these calculations of future costs is the discount rate, that allows to compare costs incurred at various points of time in the future with those incurred today. This usually results in future costs being counted at lower rates than costs incurred today, the rationale for this being a pure time-preference of people living now that the present is more relevant than the future plus the assumption that due to economic growth, future generations are better off than us and can thus better deal with such costs than we can. The choice of the discount rate has strong implications for the final cost estimates (the higher the rate is assumed to be, the less future costs will be weighted in relation to costs today; going from the 3% assumed in the cost estimates here to 5% reduces the marginal costs of methane from about US$ 1500 to US$ 670; on the other hand, decreasing the discount rate to 2.5% increases the costs to US$ 2000 (Figure 3 in Lord (2021c)).

In some cases, so-called "benefit transfer" is used to arrive at marginal cost estimates. This refers to the approach of using cost estimates available from other countries than Switzerland, in case no estimates are available for the latter. This applies for the costing of the nitrogen emissions, for example. The rationale is that the biophysical, chemical and physiological processes that link emissions to impacts are often the same, and a cost estimate in one country will differ from one in another country merely because of the nominal exchange rate and the price levels in each country. Hence benefit transfer takes the costs as estimated for another country and transfers them to Switzerland via purchasing power parity (PPP) adjustments, which is the common way to account for the exchange rate and the price level differences. As long as the underlying ecosystem and physiological processes are the same (e.g. for damages from nitrogen runoff into water-bodies or for health impacts in consequence of ammonia and particulate matter emissions), it is assumed that it is legitimate to use cost estimates from other countries after these PPP adjustments. Importantly, the social cost of carbon estimates are not differentiated by country, as GHGs are global pollutants and these estimates cover the aggregate costs incurred globally and over an extended future, thus not being specified by country.[8]

Another central aspect of hidden cost estimates are **system boundaries**, specifying which costs are included and which are not. For the case at hand here, they are displayed in Figure 3. The system boundaries for calculating hidden costs are defined by national

[8] Providing such estimate clearly is a very complex task, as decisions have to be taken on how to value damages from similar impacts (e.g. increase of sea level and flooding or impacts from droughts and heat waves) in different countries with very different socioeconomic contexts, capital and population structure.

boundaries. Thus, the SOFA cost estimates do not include the costs from the production emissions of imported food, feed, fertilizer and other inputs. The cost of imported goods are attributed to the producing countries – and similarly, the hidden costs of exported goods are not deducted from a country's balance, but attributed to it as the producer country. Thus, for example, as Switzerland does not produce any mineral nitrogen fertilizer, no mineral fertilizer production emissions are included in the SOFA 2023 hidden cost estimates for Switzerland.[9] This way of accounting – which is also the basis for national GHG inventories - means in particular, that reducing domestic production while increasing imports would result in reduced hidden costs, which would clearly not be a sustainable strategy to address hidden costs and their reduction. Furthermore, system boundaries need not only be decided regarding the attribution of the goods produced but also regarding where impacts arise. There, SOFA 2023 chooses the approach to attribute the damage caused by impact quantities to the emitting country. For example, the hidden costs of nitrogen leaching into the Rhine on Swiss territory are attributed to Switzerland, even if the environmental damage occurs later in Germany. This approach ensures that all damage caused by impact quantities is consistently attributed to the emitting country, enabling accurate country-specific calculations. Thus, biodiversity impacts of nitrogen runoff to marine ecosystems are attributed to Switzerland in case the runoff results from nitrogen fertilizer use in Switzerland (albeit the impact may arise in the Northern Sea). Biodiversity impacts from nitrogen runoff from producing grains in Germany that are then imported to Switzerland as feed are however not accounted for in the Swiss cost estimates of SOFA 2023, as the runoff does not originate in Switzerland.

[9] To make this very explicit: if a country *imports* all mineral fertilizer and does not produce any of it, then the production-related emissions from this fertilizer are not accounted for in the hidden cost assessments of the importing country. If a country *produces* mineral fertilizers (for own use but also for exporting it), these emissions are accounted for in the SOFA 2023 hidden cost assessment (as they are in the GHG inventories – albeit not in the agricultural but in the industrial sector), cf. also Figure 3 .

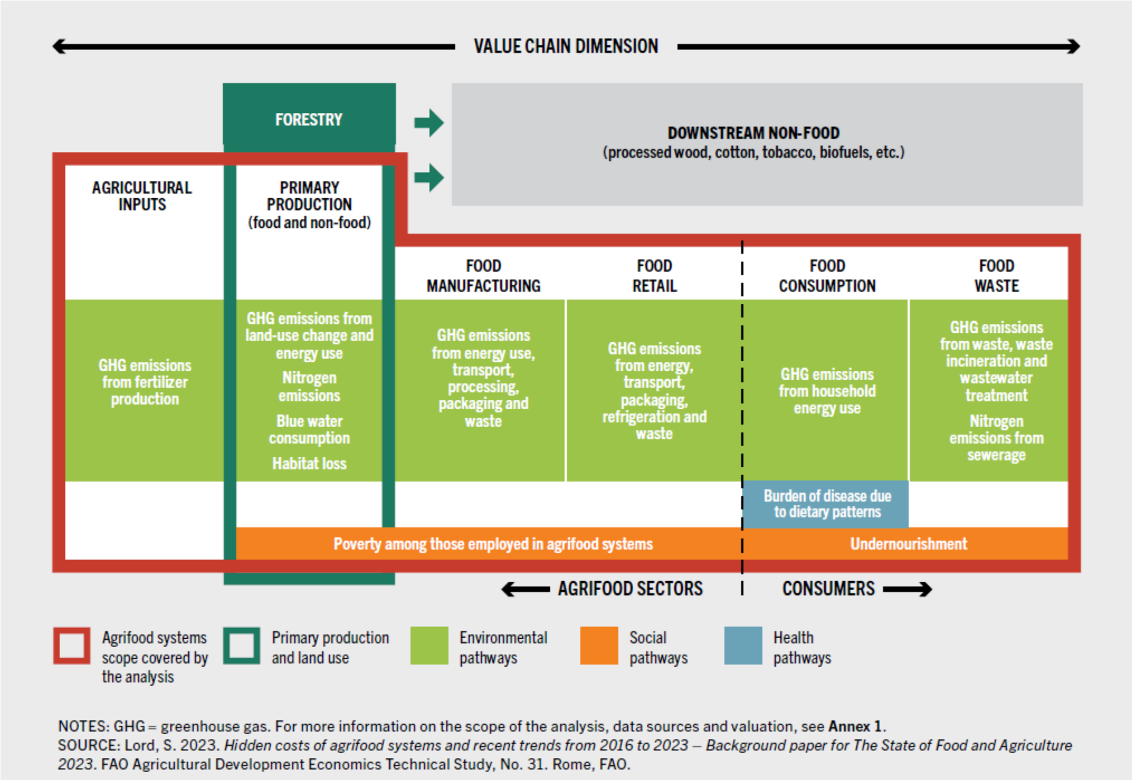


Figure 3: Scope of the analysis: system boundaries and agrifood systems stages and pathways through which hidden costs manifest (copied from figure 5 in FAO (2023))

For the assessment of hidden costs and approaches to reduce and internalize them, it is also helpful to frame the situation regarding cost producers – i.e. those causing the costs – and cost bearers, i.e. those bearing the related damages and how they relate to producers and consumers of goods and services in a market (cf. Figure 1 in section 3) The central part of this is, that in the context of hidden costs, cost bearers and cost producers do not coincide. This is the main reason why the cost producers do not account for the costs imposed on the cost bearers in their business decisions, e.g. regarding input use of pesticides, where the market price for those does not include the associated hidden costs. Clearly, as explained above, cost producers and cost bearers can also coincide while action to reduce the hidden costs is nevertheless not taken (as e.g. in the case of unhealthy dietary patterns and related immaterial costs of noncommunicable diseases).

In the following, we display the table of indicators used (see Table 1 below), as presented in table 1 in the background paper for Switzerland. This provides a clear and focused description of the indicators and cost estimates used. The "capital change" refers to which aspects are affected by the impacts that cause the hidden costs – here categorised either into natural capital loss (e.g. costs arising from biodiversity loss or resource use) or "other" capital loss (e.g. costs arising from reduced productivity which would be a human capital loss).

Table 1: "Hidden cost items from agrifood production and food consumption considered in the State of Food and Agriculture 2023 study. Cost type refers to a classification of hidden cost from environmental sources (E), productivity loss from unhealthy diets (H), and cost of distributional failures (S). Capital change refers to cost bearing arising from predominately natural (N) or predominately other (O) capital changes in the impact pathway originating with the agrifood system activity. More detail on quantity and marginal cost data is in the Methodology section." (copied from the background paper on Switzerland (Lord, 2023b))

Cost Category	Item	Impact Quantity	Cost Type	Marginal Cost	Cap -ital
GHG Emissions	GHG Emissions (CH4): Farm-gate emissions	CH4 metric ton	E	Social cost of CH4 – residual damages to global future GDP PPP from agricultural losses in NPV at the optimal amount of abatement, attributed to the country of emission	N
	GHG Emissions (CH4): Land Use change				
	GHG Emissions (CH4): Pre- and post- production				
	GHG Emissions (CH4): Farm-gate emissions			Social cost of CH4 – residual damages to global future GDP PPP from mortality in NPV at the optimal amount of abatement, attributed to the country of emission	O
	GHG Emissions (CH4): Land Use change				
	GHG Emissions (CH4): Pre- and post- production				
	GHG Emissions (CO2): Farm-gate emissions	CO2 metric ton	E	Social cost of CO2 – residual damages to global GDP PPP from agricultural losses in NPV at the optimal amount of abatement, attributed to the country of emission	N
	GHG Emissions (CO2): Land Use change				
	GHG Emissions (CO2): Pre- and post- production				
	GHG Emissions (CO2): Farm-gate emissions			Social cost of CO2 – residual damages to global future GDP PPP from mortality in NPV at the optimal amount of abatement, attributed to the country of emission	O
	GHG Emissions (CO2): Land Use change				
	GHG Emissions (CO2): Pre- and post- production				
	GHG Emissions (N2O): Farm-gate emissions	N2O metric ton	E	Social cost of N2O – residual damages to global future GDP PPP from agricultural losses in NPV at the optimal amount of abatement, attributed to the country of emission	N
	GHG Emissions (N2O): Land Use change				

	GHG Emissions (N2O): Pre- and post- production				
	GHG Emissions (N2O): Farm-gate emissions			Social cost of N2O – residual damages to global future GDP PPP from mortality in NPV at the optimal amount of abatement, attributed to the country of emission	O
	GHG Emissions (N2O): Land Use change				
	GHG Emissions (N2O): Pre- and post- production				
Water use	Blue water withdrawal: Agricultural use	Cubic metre	E	Agricultural losses and productivity losses in the country of withdrawal due to burden of disease from protein energy-malnutrition, in the present and future in NPV, due to water deprived from economic use.	N
Land-use change	Land-use change: Cropland to Forest	Effective hectares of habitat returned (ha)	E	Value of equivalent hectares of present and future returned ecosystem services in NPV in the country of land-use transition due to recovery or re-establishment of ecosystem	N
	Land-use change: Cropland to Unmanaged Grassland				
	Land-use change: Pasture to Forest				
	Land-use change: Pasture to Unmanaged Grassland				
	Land-use change: Forest to Cropland	Effective hectares of habitat lost (ha)	E	Value of equivalent hectares of present and future lost ecosystem services in NPV in the country of land-use transition due to loss of natural ecosystem	N
	Land-use change: Forest to Pasture				
	Land-use change: Unmanaged Grassland to Cropland				
	Land-use change: Unmanaged Grassland to Pasture				

Nitrogen emissions	NH3 emissions to air	NH3 N-kg	E	Productivity losses in the country of emission due to burden of disease from particulate matter formation	O
				Agricultural and ecosystem services losses from nutrient imbalance and acidification of terrestrial biomes due to deposition, ecosystem services losses from nutrient imbalance, acidification and eutrophication of riverine, wetlands, and coastal systems due to deposition run-off	N
	NOx emissions to air	NOx N-kg	E	Productivity losses in the country of emission due to burden of disease from particulate matter formation	O
				Agricultural and ecosystem services losses from ozone formation, nutrient imbalance and acidification of terrestrial biomes due to deposition, ecosystem services losses from nutrient imbalance, acidification and eutrophication of riverine, wetlands, and coastal systems due to deposition run-off	N
	NO3- leached to groundwater	NO3- N-kg	E	Productivity losses in the country of emission due to burden of disease from human nitrate intake	O
	NO3- loads due to run-off from agricultural land to surface water			Ecosystem services losses from nutrient imbalance, acidification, and eutrophication riverine, wetlands, and coastal systems due to run-off	N
	NO3- loads due to effluent or human sewerage in surface water			Ecosystem services losses from nutrient imbalance, acidification, and eutrophication riverine, wetlands, and coastal systems due to run-off	N
Poverty	Agrifood system worker poverty headcount at $3.65 a day (2017 PPP)	ppl	S	Cost in PPP terms of the income shortfall below moderate poverty line of agrifood workers	O
Undernourishment	Number of Undernourished	ppl	S	Productivity losses in the country of consumption due to burden of disease from protein energy-malnutrition.	O
Dietary patterns	Burden of non-communicable diseases and high body-mass-index (BMI) attributable to dietary intake	Burden of disease in disability adjusted life years (DALYs)	H	Productivity losses in the country of consumption due to burden of disease from high body-mass index and noncommunicable diseases	O

5.2 Results for Switzerland from SOFA 2023

This sub-section summarises the findings of the 2023 SOFA report for Switzerland, providing a basis for discussion and refinement. *Figure* **4** gives an overview of the total hidden costs and illustrates the link between cost producer and cost bearer. The impact quantities in the middle of the figure represent the hidden cost producing source. These sources can be compiled into three cost types namely Environment (E), Health (H) and Social (S) on the left-hand side of the figure. These hidden health costs cover only costs related to the productivity losses due to unhealthy diets, and thus do not include the costs of adverse health effects from production-related emissions, such as NH_3. The latter are assigned to hidden environmental costs. How these relate to health costs is made visible on the right-hand side of this figure. This shows the cost bearer represented by the capital change area which are natural capital (N) and other capital (O) (cf. section 5.1 above). This figure thus shows that also the cost types allocated to the environment cause largely impacts on "other" capitals, i.e. mainly related to health aspects.

This classification of costs to environmental or health contexts can be confusing. Many environmental impacts, such as NH_3 emissions, cause hidden costs in the health impact area and one might expect them to be counted there. For a focus on cost producers and pathways towards cost reduction, the classification of hidden costs according to causes rather than impacts is however most helpful. Other studies approach this differently. Perotti (2020), for example, categorizes costs according to impact areas and thus includes the health costs from NH_3 emissions in the total health costs and not in the environmental costs.

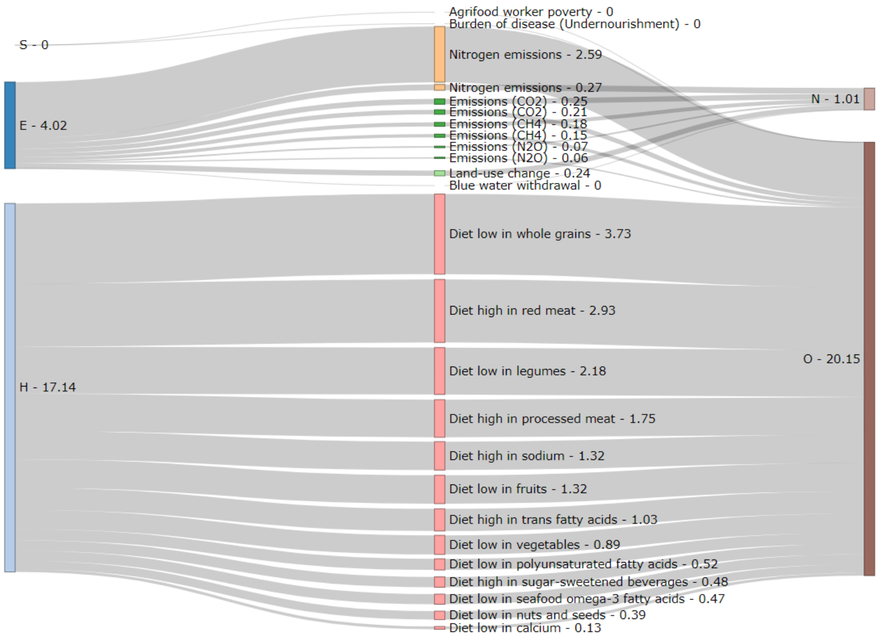


Figure 4: Sankey Diagram of total hidden costs of Switzerland according to SOFA 2023 (numbers: costs in billion CHF), divided into cost type on the left (E for Environmental and H for Health (S for Social is not shown as the value is zero)), the cost items in the middle and the capital (N for Natural and O for Other capital) on the right side. Based on the results of the State of Food and Agriculture 2023 study, as presented in the background paper on Switzerland (Lord, 2023b)) and the refined health costs as provided by the FAO SOFA team.

The following Figure 5 shows the composition of the Swiss hidden costs divided into the three cost types. The bar chart to the left shows the total hidden costs (21.1 billion CHF; 19.1 US$ 2020 PPP)[10], with 17.1 billion CHF (15.5 billion US$) related to unhealthy diets, 4.0 billion CHF (3.6 billion US$) from environmental sources (E) and none from social distributional failures (S), thus not visible in the figure. The other bar charts in the middle and to the right present further details on the health and environmental costs.

[10] With a PPP conversion factor of 1.105 (World Bank, 2024)

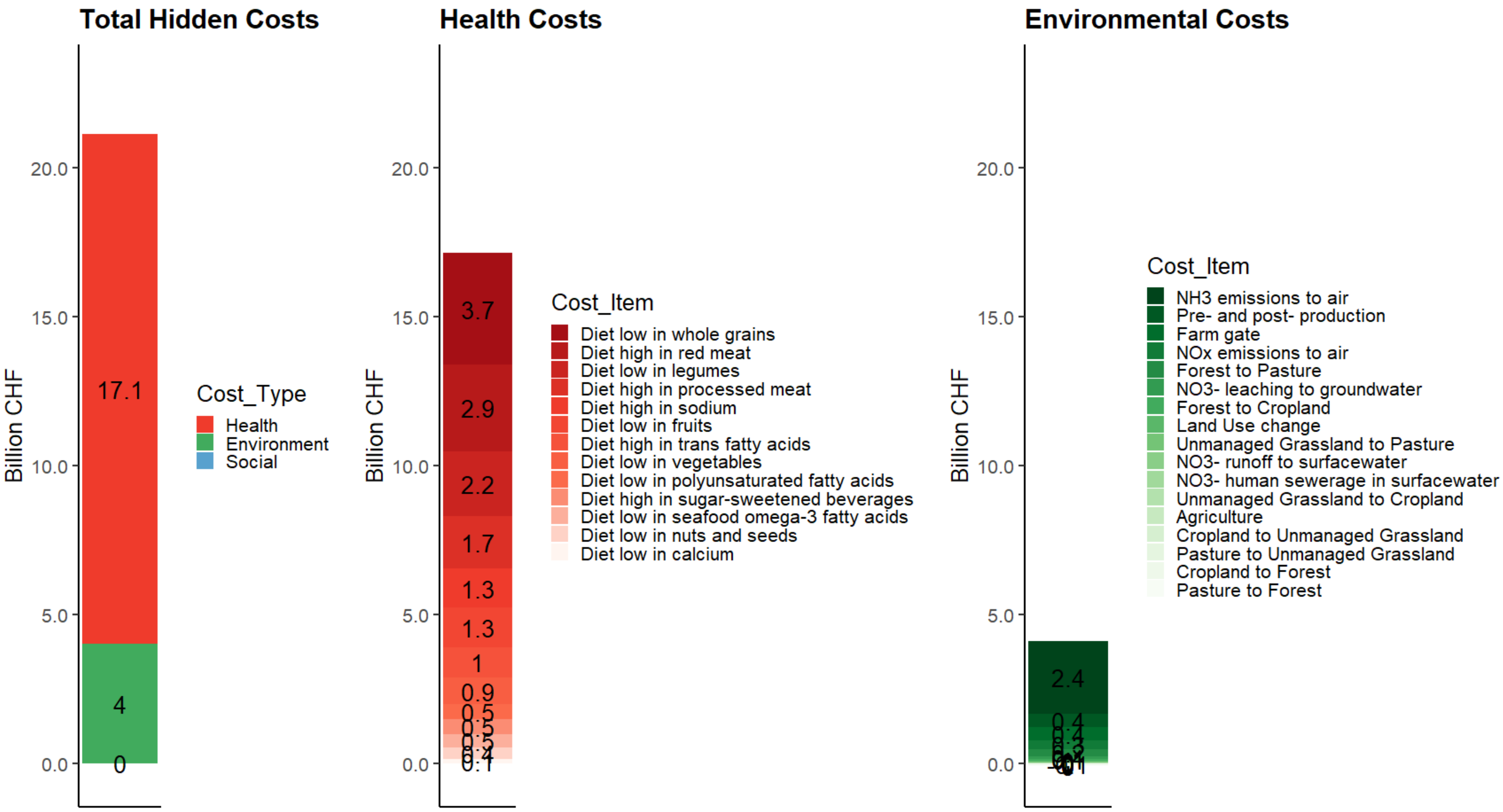


Figure 5: left: Total hidden costs of Switzerland according to SOFA 2023 divided into the three cost types: Environment (E), Health (H) and Social (S); middle: hidden costs of the cost type health (H); right: hidden costs of the cost type environment. The scales of the y-axes are different in all graphs for better display of the information. Based on the results of the State of Food and Agriculture 2023 study, as presented in the background paper on Switzerland (Lord, 2023b)) and the refined health costs as provided by the FAO SOFA team. Uncertainties amount to 11-25 billion CHF for health, 2-8 billion CHF for the environment and in total 13-33 billion CHF (cf. end of this section).

The hidden costs of unhealthy diets form the largest contribution with CHF 17.1 billion (15.5 billion US$ 2020 PPP).[11] These costs are derived from the Global Burden of Disease study that classifies health risks related to dietary patterns. The burden of disease is expressed in disability-adjusted life years (DALY). The SOFA 2023 derives the DALYs which fall within the system boundaries of the food system namely all nutrition-related health risks. This DALY number then corresponds to the number of lost (working) years due to an unhealthy diet. To arrive at a cost estimate this is then multiplied by the marginal costs, which here for the SOFA 2023 is chosen as the average labour productivity in Switzerland, measured in GDP per labour force[12]. This results in the lost productivity as hidden costs. The cost type health and its risks can be seen in Figure 5 middle panel). Diets low in whole grain, high in red meat and low in legumes are among the largest factors.

Hidden costs from environmental sources amount to CHF 4.0 billion (3.6 billion US$ 2020 PPP). Nitrogen emissions contribute most with CHF 2.9 billion (2.6 billion US$ 2020 PPP) (cf. Figure 5, right panel). Airborne ammonia emissions, which result in lost productivity due to the disease burden associated with the formation of particulate matter that affects respiratory and cardiovascular health, and adverse impacts on ecosystem services, are by far the largest cost item. (cf. Figure 5, right) of the cost type environment, accounting for 12% of total and 60% of environmental hidden costs. The hidden costs are due to the calculated 55 million kg N emissions with marginal costs of about CHF 44 per kg N (US$ 40 2020 PPP per kg N).[13] These are national numbers and with this national data, no refinement regarding different sectors or regions are possible. The SOFA 2023 report does not report any social costs from undernourishment or poverty of agricultural workers for Switzerland, as they are identified to be zero under the assumptions taken (e.g. a poverty line of US$ 3.65 per capita and day, PPP 2017, with a PPP conversion factor of 1.188 for 2017 corresponding to about CHF 4.34 (World Bank, 2024)).

We shortly also report the overall uncertainties that come with these numbers: these are 11-25 billion CHF for health costs and 2-8 billion CHF for environmental costs, in total 13-33 billion CHF (Lord, 2023b).[14]

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[11] We here display a and discuss the results from the SOFA 2023 estimates with the adjustments in health costs undertaken in early 2024, resulting in a reduction from CHF 20.8 to CHF 17.1 billion (18.8 to 15.5 billion US$ 2020 PPP). For details, see section 6.2.1.

[12] For further details on this marginal cost estimate, see section 6.2.1.

[13] The marginal costs for the health impacts being about 36.7 US$ 2020 PPP per kg N and the marginal costs for the impacts on ecosystem services (deposition) about 3.5 US$ per kg N).

[14] Lord (2023b) reports 12-27 billion 2020 PPP US$ for health and 1.5-7 billion 2020 PPP US$ for environmental costs; with the correction from the central estimate of 18.8 billion to 15.5 billion 2020 PPP US$ and the conversion factor 1.105 to CHF this results in the values reported here.

6. Refinements of the estimates and additional costs covered in the case study

This section discusses potential refinements of the hidden cost estimates from SOFA 2023 for Switzerland, both based on more detailed data for the indicators already included, and by suggesting amendments with additional indicators of particular relevance to the Swiss case. First, we shortly present additional indicators of potential relevance to the hidden cost assessment, based on current and recent policy debates and developments, as well as on expert inputs. We then address how the existing indicators could be refined (sub-section 6.2) and how additional indicators may be identified and developed (sub-section 6.3). The last sub-section 6.4 brings all this together to provide a first gross updated estimate of the hidden costs of the Swiss agrifood system. For these refinements and amendments we also refer to a number of studies that undertake hidden cost estimates for the Swiss agrifood systems, such as Dümmler and Roten (2018), Perotti (2020) and Schläpfer (2020). We then also present the findings from these studies in comparison to our refined and amended estimates in this summarising sub-section 6.4. Finally, we emphasize that we aim at deciding rather conservatively when refining existing or adding new cost estimates.

6.1 Swiss context – key documents and debates

Recent and ongoing (and also future) key debates in the national agrifood context as well as of the existing and planned regulatory framework and sustainability monitoring, serve to identify important additional topics of potential relevance for hidden cost estimates. Thus, additional indicators can be taken from the various public and governmental debates, documents and processes, such as the "Agrar-Umweltmonitoring/ Monitoring des Agrarumweltsystems Schweiz MAUS" (Agroscope, 2024a)[15], "Umweltziele Landwirtschaft" (FOEN, 2008), the "Zukünftige Ausrichtung der Agrarpolitik 2030"(Bundesrat, 2022) and a number of specific monitoring activities. From these, the following additional indicators and some more general topics to be accounted for in the quantification of related hidden costs can be identified[16]:

1) "Agrar-Umweltmonitoring" (Agro-environmental monitoring)
   - Phosphorus
   - Pollutants in soils / soil fertility
   - Pesticides / Toxicity (impact on water bodies)
   - Biodiversity - landscapes

[15] This has two parts, the "Nationales Agrarumweltmonitoring" (national agro-environmental monitoring), covering data till 2021/22: link; and a regional and farm-specific monitoring based on data from around 300 farms for 2009-2022 from ZA-AUI: link. From 2025 onwards, new data will be available within the new monitoring «Monitoring des Agrarumweltsystems Schweiz MAUS» that replaces these other two (link).

[16] Indicators and topics already covered in SOFA 2023 such as GHG emissions or N-pollution are not listed again. Other indicators not covered by these sources but deemed important by the experts of the monitoring group are neither included here but are addressed further down.

- Antibiotics use (impact on water bodies)
- Soil erosion risk

2) "Umweltziele Landwirtschaft" (environmental targets for agriculture)
   - Water (ecosystem quality)
   - Diesel exhaust particulates
   - Biodiversity – genetic diversity (general and agricultural) / ecosystem services
   - Soil erosion
   - Soil compaction
3) "Zukünftige Ausrichtung der Agrarpolitik 2030" (translated: "future orientation for agricultural policy 2030"); this process defines objectives but not the indicators how to measure them. However, FOAG will have to report on them in 2025 in the "Zwischenbilanz" (intermediate assessment). In the course of this, suitable indicators are being defined.
   - Food waste
   - N imports (via feed imports)
   - Low system-level nutrient use efficiencies due to cropland-based feed production
   - N emissions/losses stay within ecological carrying capacities
   - Quality of biodiversity (increase of high quality for biodiversity).
4) Specific monitoring and indicator systems:
   - ALL-EMA, Biodiversity monitoring (Agroscope, 2024b)
   - NAQUA, national monitoring of groundwater (FOEN, 2019a)
   - NAWA, national monitoring of surface water quality (FOEN, 2023b)
   - Footprint perspective for consumption, there is a range of indicators, e.g. related to land-use related biodiversity impacts, water stress, marine eutrophication due to nitrogen, etc., also in the aggregate metrics of "eco-points" ("Umweltbelastungspunkte" UBP). Cf. also data from Federal Statistical Office (FSO) on the greenhouse gas footprint (FSO, 2022) and from FOEN on other environmental footprints (Nathani et al., 2022).

Based on expert inputs from the project monitoring group, an initial assessment of data availability and the relevance of these various aspects was undertaken in the first quarter of 2024:

- Ecosystem quality, biodiversity/landscapes, ecosystem services: no monitoring available
- Soil fertility, soil erosion and soil compaction: no representative data available
- Impacts of antibiotics use on water bodies: no monitoring available, but there is some monitoring of antibiotics use (BLV, 2023)
- Nitrogen imports: difficult to source data

Furthermore, some amendments not named explicitly in the sources above are suggested by the monitoring group:

- related to soils, some specific monitoring of drained organic soils and related soil organic carbon losses would be warranted[17].
- Regarding antibiotics use, impact on human health should be addressed, and there is in particular the development of resistant germs as a large impact with potentially large hidden costs.
- Similarly, for pesticide use, not only the impact on water bodies but also the health impacts on humans are relevant (EEA – European Environment Agency, 2023). Some indicators for residues of plant protection chemicals in drinking water, in air and in food commodities would be very helpful.
- Regarding water, not only ecosystem quality but also its quality as drinking water or the costs related to assuring such in a context of pollution should be covered.
- Animal welfare is a topic of broad societal interest in Switzerland and potential hidden costs related to animal welfare deficits should be covered as well, if possible.
- Finally, hidden benefits should also be addressed, albeit opinions differ to which extent and level of detail this should be done (cf. section 6.3 below).

The following additional topics are suggested to be investigated in more depth, based on the relevance as identified with the monitoring group, and also consolidated with this group in specific meetings and feedback rounds on earlier drafts of this report (albeit data availability may pose considerable challenges, as indicated above).

- Phosphorus surplus
- Soil health, soil fertility, soil quality (there, work in the context of the "Bodenindexpunkte" (sanu, 2024) may be helpful); drained organic soils and their soil organic carbon losses
- Biodiversity/ecosystem state and loss (various types of indicators, species, habitats, etc.)
- Use and impacts of plant protection chemicals, in particular human health costs
- Antibiotics use and antibiotics resistances and related human health costs
- Animal welfare
- (Hidden benefits)[18]

Furthermore, the following two aspects have been discussed in the monitoring group and we also address them as complements to The SOFA 2023 estimates for Switzerland:

- Hidden costs related to subsidies and other incentives
- Hidden costs related to food, feed and production input imports

[17] Cf. Wüst-Galley et al. (2020); these estimates will be updated in the near future.

[18] Hidden benefits are put in brackets as their inclusion was suggested by some members of the monitoring group, while others had reservations towards this. We suggest to not include hidden benefit estimates but rather highlight their importance qualitatively, cf. section 4.

As a general remark, it was also voiced that such hidden cost assessments should allow to cover aspects that are not yet central to the debates today but may gain strong future interest, e.g. due to climate change impacts. A prime example is water scarcity, as an amendment of the blue water use indicator covered in SOFA 2023 (water scarcity will be addressed in sub-section 6.2.4 below). Finally, it is important to notice that this list has large overlaps with the list of potential amendments (data permitting) discussed in the SOFA 2023 background paper on the hidden costs of the Swiss agrifood system. This list from the SOFA 2023 background paper was developed on the background of a potential refinement that is largely consistent with the SOFA 2023 estimates rather than on the basis of most important political debates in Switzerland. We copy table 8 from this report below which was developed in this background paper specifically for the Switzerland (cf. Table 2):

Table 2: "Summary of cost categories and compatible components for future inclusion in agrifood hidden cost studies." (copied from the background paper on Switzerland (Lord, 2023b))

Category	**Components**	**Agrifood attributable global cost to society annual estimate from literature**	**Comment**
Phosphorous	Run-off of soluble P compounds from synthetic fertiliser application and manure	Unclear due to agrifood nitrogen costing including current phosphorous loading.	Interaction with N loading. Develop marginal costs of N and P for future cost-benefit studies.
Soil erosion	Lost agricultural productivity (imperfect information) Dust (externality) Sediment (externality)	Productivity loss ~200 billion US2020 (exchange rates), ~200 billion 2020PPP (guess on air pollution from dust), sediment unknown	Nutrient loss through erosion and CO2 net emissions accounted in GHG and N categories.
Pesticides	Worker occupational exposure burden of disease (imperfect information) Ecosystem service losses including pollination services (externality)	Productivity loss, unknown globally, extrapolating China and US, 100 billion 2020PPP Attributed loss of pollination services, ~200-500 billion US2020 assuming 50% of loss of pollination services is attributable to pesticides	Marginal costs dependant on stocks in the environment and state of nature – risk of future collapse in biodiversity and pollinators.
AMR	Burden of disease from human infections (externality)	200-400 billion 2020PPP	Emerging trend. Uncertainty in level of attribution from use in livestock.
Undernutrition	Dietary Iron Deficiency (distributional failure or imperfect information)	1 trillion 2020PPP	Emerging trend. Correlates with broader poverty determinates such as living wages.

6.2 Refining the SOFA 2023 cost estimates

When using the hidden cost estimates from SOFA 2023 for more detailed country-level analysis, it should be briefly checked whether the figures used in SOFA 2023, which are taken from globally consistent datasets covering most countries, are consistent with the central country-specific data sets and the available national thematic reports. This has two components, namely the data on the value of the impact categories (quantity), and second, the data on the marginal cost values used for those. For greenhouse gas emissions, for example, this means to compare the emissions data in the SOFA 2023 report that are taken from FAOSTAT to the emissions data reported in the national greenhouse gas inventory. It then also means to compare the values assumed for the social costs of carbon in the SOFA 2023 report to any such cost estimates that exist in the specific country. In Switzerland, this can for example be taken from the context of external costs of traffic, where ample information from thorough studies is available, also covering assumptions on social costs of carbon values (ARE, 2023a).

Such consistency check can usually be done relatively easy and, if discrepancies arise, using the more detailed national data is warranted, in order to be consistent with the data that is referred to and used in the country-specific discourses and policy debates. Such refinements also potentially allow to better identify where the hidden costs arise on a sectoral level or differentiated for various actors, which could then offer a refined basis for developing targeted interventions for effective transformation pathways.

In the following, such consistency checks are undertaken for the cost categories covered in the SOFA 2023 report, and potential refinements are suggested where adequate. We emphasize again that the numbers used here come with large uncertainties and we work with rounded numbers – hence calculations may also show some irrelevant rounding errors in the digits.

6.2.1 Health

SOFA 2023 addresses health costs in various places, namely related to unhealthy diets as well as to health impacts of air and other pollution, e.g. from NH_3 emissions or as part of the impacts of climate change as covered in social costs of carbon estimates. However, SOFA 2023 reports only diet related health costs under the heading of "health". Consequently, health costs related to environmental impacts are taken into account in the environment category. The health costs reported in SOFA 2023 are thus not the total health costs of the agrifood system but of consumption only. The reason for this is, that when allocating hidden costs, the focus is placed on identifying the cost producers rather than the cost bearer. This can also be done differently (see chapter 3), and when displaying the SOFA 2023 estimates, we also provide all health costs together as complementary information to the original presentation from SOFA 2023 (cf. Figure 4). This then emphasizes a focus on who bears the costs and less so on their causes.

For Switzerland, there is an extensive basis of knowledge on direct and indirect or potentially hidden health costs available from the discussion on hidden costs of traffic

(ARE, 2023a; Ecoplan/Infras, 2014; Infras & ecoplan, 2019)[19]. The biggest difference in their assessments of health costs is the inclusion of direct treatment costs, costs of job replacements and immaterial costs due to physical and mental suffering, besides the productivity losses that are the only category covered in SOFA 2023.

6.2.1.1 Health costs due to productivity losses related to dietary risks

The Global Burden of Diseases data (GBD, 2019) provides "Disability-adjusted life years (DALY)" values for dietary risks.[20] For Switzerland, those amount to 225'000 DALY in the original SOFA 2023 estimates. Using the marginal cost factor for DALY (almost 84'000 US$ 2020 PPP, i.e. almost CHF 93'000 per DALY[21]), the related costs are derived. SOFA 2023 assessed the related health costs in combination with the DALYs attributed to high body mass index (BMI-DALY), which bears the danger of some double counting. To account for this, SOFA 2023 considered 75% of BMI-DALYs to be related to dietary risks and not to other causes, such as low physical activity.

This assessment of the Global Burden of Disease study has since been amended and SOFA 2024 utilizes a somewhat different assessment of the dietary health costs, avoiding the rather arbitrary allocation factor of 75%. Unlike before, the DALYs due to diets high in sugar-sweetened beverages are now explicitly included, while the DALYs due to high Body-Mass-Index BMI are excluded, as most or even all of the underlying causes related to the agrifood system are now captured by the other health risk factors included, thus avoiding double counting. In the case of Switzerland, this change in DALY-categories covered results in a dietary risk of almost 186'000 DALYs, leading to external costs of about US$ 15.5 billion (CHF 17.1 billion) due to the productivity losses related to these dietary risks. Top dietary risks are diets low in whole grain (22%), diets high in red meat (17%), low in legumes (13%) and high in processed meat (10%), followed by low in fruits and vegetables and high in sodium and trans-fatty acids. The diseases covered are neoplasms, cardiovascular disease and type-2 diabetes associated with these unhealthy dietary patterns.

It is important to emphasize that the costs related to productivity losses differ between the traffic costs studies in Switzerland mentioned above and SOFA 2023. The former report net losses of production at about CHF 14'500 per productive year lost (i.e. lost if one labour force loses one year of productive activity) (Ecoplan/Infras (2014), p 144) as the basis for their calculations (this is the national gross income minus national gross expenses of the total national labour force). This is almost by a factor of seven smaller than the SOFA 2023 estimate, which is based on GDP divided by labour force, resulting in CHF 93'000 (84'000 US$) that are lost if a labour force loses one year of productive

[19] Currently, an ongoing project commissioned by the Federal Office of Public Health FOPH works on providing new estimates on the costs of communicable and noncommunicable diseases and of the risk factors inactivity and overweight in Switzerland. Results are expected in the first half of 2025 (Volkswirtschaftliche Kosten von NCDs | MonAM | BAG).

[20] DALYs thus stand for years in good health lost due to the diseases.

[21] With a PPP conversion factor of 1.105 (World Bank, 2024); derived as GDP per labour force, using the values from SOFA 2023 (Lord, 2023b).

activity. The number used in the traffic-study was however updated to net productivity losses of CHF 21'000 in 2015 and it was then also changed from net to gross income as a basis for their calculations. This results in a value of almost CHF 100'000, which is now used as a basis for the calculations (Infras & ecoplan, 2019). This is slightly higher but comparable to the estimate of CHF 93'000 per labour force used in SOFA 2023 and just reported above.

6.2.1.2 What counts as hidden costs related to health and what does not?

Furthermore, there needs to be an in-depth discussion of which health-related costs are deemed hidden and which not, as well as which of these costs are really attributable to the food system. In the SOFA 2023 report, the costs of medical treatments are excluded from the analysis altogether, while productivity losses are included. There is no discussion of whether they are driven by the agrifood systems or other factors or why this separation is helpful. One reason is that treatment costs are not hidden but covered by health insurance, i.e. only indirectly by the consumers. On the other hand, the increasing burden of non-communicable diseases, whereof a significant part is related to diets and thus to the agrifood system, increases health system costs, which also has adverse effects on many stakeholders (cf. also section 3).

SOFA 2023 does neither cover a number of clearly hidden costs, such as costs of antimicrobial resistances (cf. section 6.3.5), or costs related to effects further down a cause-effect chain, such as from communicable diseases (e.g. related to reduced immune system performance due to unhealthy diets - cf. e.g. the correlation between diet-related noncommunicable diseases and correspondingly stronger impacts of infectious diseases such as COVID-19 -, and other health impacts of the agrifood system, such as air pollution or pesticide use) or from a higher demand for doctors due to the dietary health related diseases and the corresponding opportunity costs of them doing something more productive for society. All these are not covered due to lack of globally consistent (and often any) data, which is a prerequisite for the inclusion in the global SOFA 2023 assessment.

6.2.1.3 Refinement of hidden health costs: direct treatment costs

Direct treatment costs related to diets may be estimated from the numbers of (Stucki et al., 2023). They report that about 20% of direct health costs relate to cardiovascular diseases, cancer, diabetes and other noncommunicable diseases (Table 3 in Stucki et al. (2023)). Unhealthy diets are the root cause for a large part of these costs. Doing a gross and cautious estimate, we assume that half of this is related to diets, which then results in direct health costs of about 8 billion CHF in 2017 (about 7 billion US$).

6.2.1.4 Refinement of hidden health costs: immaterial costs

Importantly, the immaterial costs (related to physical and mental suffering from sickness, estimated via willingness-to-pay for avoidance of such suffering) are by far the largest category in (Infras & ecoplan, 2019), amounting to seven times the productivity losses as compared to the original study and about on par with productivity losses after updating to their gross value. These immaterial losses are calculated via the "years of life lost" and the "years of healthy years lost" treated separately, while in SOFA 2023, the calculations are based on "disability adjusted life years" (DALYs), that are the weighted averages of the other two, where the choice of the weight centrally influences the resulting values (cf. footnote 198, page 237 in Ecoplan/Infras (2014)). The immaterial costs are then quantified via the "Value of statistical life" (VOSL) and the "Value of life year lost" (VLYL), based on the willingness-to-pay of the population to reduce mortality risks.[22] The latter annual value can be seen as a more encompassing estimate of health costs linked to lost healthy years of life (i.e. due to premature death and also due to years with diseases), also including the immaterial costs directly borne by the patient and not only covering productivity losses.

These estimates for immaterial costs are very uncertain and used with large uncertainty ranges of e.g. +/-50% (Ecoplan, 2016). Furthermore, it is difficult to identify, which cost categories are covered in the willingness-to-pay estimates and which not, in particular, whether part of the foregone income due to illness is covered or not (cf. figure 3-2 in Ecoplan (2016)). Commonly, it is suggested that these parts related to productivity losses are not included in willingness-to-pay estimates and for the total estimates the gross productivity losses are thus added. Therefore, we subtract the corresponding value of about CHF 100'000 for productivity losses per labour force from the updated total estimate of CHF 235'000 to not double count and to only cover the immaterial costs, thus at about CHF 135'000. Given that this estimate may still include part of the material costs (fig 3-2 in Ecoplan (2016)) and given the large uncertainties, we use a conservative lower estimate of also about CHF 100'000 for the immaterial costs. Applying this to the diet related DALYs (186'000) results in immaterial costs of about 18 billion CHF annually (about 16 billion US$ 2020 PPP). Adding an (arbitrary) uncertainty margin of 50% due to the unknown[23] weighting between "years of life lost" and "years of healthy years lost" when going from the mainly respiratory disease-based health impacts from traffic to the various noncommunicable diseases related to unhealthy diets, we thus arrive at 9 billion CHF (8 billion US$). Accounting for these costs then results in a measure for the willingness-to-pay for life quality and longer life.

Different to the situation for traffic, where cost producer and cost bearer do largely not coincide for the health impacts, in the case of food, these costs related to individual suffering (immaterial costs) are clearly private costs not borne by society, or only to a minor part in as much as this suffering would add further productivity losses not yet covered in those addressed by the DALYs. Similarly, direct treatment costs are not hidden but internalized in the context of the health insurance system (with potentially biased incentives with which insurance solutions may unavoidably come with, cf. section 3) and job replacement costs are neither borne by society but rather remain in the business sphere. Nevertheless, the mere size of health costs related to an unhealthy diet

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[22] In Ecoplan/Infras (2014), values of 3.4 million CHF and 100'000 CHF respectively were assumed. The update in Infras & ecoplan (2019) resulted in double these amounts, based on more and much more robust data (CHF 6.5 million and CHF 235'000). Current newest values from ARE (2023b) are again somewhat higher.

[23] This could be derived from the information on the DALYs per different NDCs related to unhealthy diets, but this is beyond the scope of this study.

warrants some societal awareness, given that these likely arise not in a fully informed decision context on individual diets. These decisions are also influenced by obesogenic food environments, etc. that then bring them closer to hidden costs of the agrifood system (cf. section 3). We hence suggest to not refine the productivity loss part of the health cost assessment of SOFA 2023 for Switzerland as this would result in relatively small changes only and uncertainties would remain high. However, in the spirit of using the hidden cost estimates for identifying where transformation may be most needed, we suggest to provide the information on these additional cost categories of direct treatment costs and immaterial costs.

Summarizing, the hidden health cost estimates from SOFA 2023 will be kept without refinement (17.1 billion CHF; 15.5 billion US$), but they will be complemented by the numbers for the direct (8 billion CHF; 7 billion US$) and immaterial health costs (9 billion CHF; 8 billion US$).

6.2.2 Greenhouse gas emissions and social costs of carbon

The total CH_4 emissions for 2020 in Switzerland amount to 181'890 tons, of which 151'150 tons come from agriculture.[24] 85% of this comes from livestock farming (thereof 94% from cattle) and 15% from farmyard manure management. About 19'880 tons of CH_4 emissions are attributed to the waste sector, whereof part relates to the food sector. These waste emissions are recorded in the SOFA report under pre- and post-production.

National data show total N_2O emissions of about 11'310 tons. 5'970 tons are generated in agriculture. These emissions are mainly caused by fertilizer application to managed soils and manure left on pasture (4'690 tons) and manure management (1'280 tons). The waste sector contributes 2'290 tons.

These CH_4 and N_2O emissions from national data are largely comparable to the values used in the SOFA 2023 report. The biggest difference arises for emissions from pre- and post-processing (manufacturing of fertilizers, food processing, packaging, transport, retail, household consumption and food waste disposal), where the values in SOFA 2023 are about 30-50% higher than those reported nationally (FAO, 2024a).[25]

In SOFA 2023 for Switzerland, CO_2 emissions allocated to the agrifood system are much higher than the CH_4 and N_2O emissions. The explanation is that these CO_2 emissions also cover pre- and post-processing emissions and not only those from agriculture directly as covered in "Sector 3 Agriculture" in the GHG inventory report. These come mainly from food processing and food transportation. CO_2 emissions from land use change stem mostly from net forest conversion. Two thirds of farm gate CO_2 emissions are from

[24] These and the following numbers are taken from the National GHG Inventory Report for 2023, referring the year 2020 (FOEN, 2023c) and from the emissions data from FAOSTAT (FAO, 2024a).

[25] FAO changed their calculation methodology in 2023, while SOFA 2023 still uses the numbers based on the old methodology before these changes. This explains the discrepancy (personal communication of Steven Lord, mail 9.4.2024). Details on the methodological changes behind these differing numbers are however not available from the FAOSTAT metadata.

drained organic soils and one third from farm energy use. As above with methane and nitrous oxide, SOFA 2023 reports considerably higher pre- and post-processing CO_2 emissions than the national data (namely 6.3 million tons CO_2 instead of 4.7 million tons CO_2 (FAO, 2024a)), i.e. by about 35 percent. Finally, there are the 0.5 million tons of CO_2 emissions from land use change in the SOFA 2023 report on Switzerland that correspond to the similar amount of emissions from the net change in mineral and organic soils as reported in the national GHG inventory (FOEN, 2023c).

The discrepancies in pre- and post-processing emissions for CH_4 and N_2O results in minor corrections to the total CH_4 and N_2O emissions only. For CO_2, however, the discrepancy results in a more significant difference. In total, using the numbers from FAO (2024a) instead of SOFA 2023 (Lord, 2023b) for pre- and post-processing results in emissions that are about 10% lower in CO_2e. We thus use this correction factor of 0.9 to the emission estimates from SOFA 2023 to account for these changes in the data. As mentioned above, this discrepancy is due to methodological changes at FAOSTAT in 2023 (cf. previous footnote). Given the size of the difference, it is not of central relevance, though. SOFA 2023 specifically seems to include emissions from energy use in synthetic fertilizer production in the pre- and post-processing category (different to the current FAO data), but this results in emissions of about 0.18 million t CO_2e only (cf. section 6.3.8), thus an order of magnitude smaller than the discrepancy between SOFA 2023 and FAO. We report these emissions from fertilizer production separately under emissions from imports (section 6.3.8).

The choice of the value for the social costs of carbon is central for the magnitude and relative importance of the costs of GHG emissions. It is important to note that SOFA 2023 works with gas-specific values, i.e. does not multiply converted CO_2-equivalent values with the social costs of carbon rate for CO_2e but applies the different rates provided separately for CO_2, CH_4 and N_2O by the US-EPA to the respective emission quantities of these gases. This allows to account for the different time-dynamics of these three gases, which is necessary for a correct cost estimation (Lord, 2021c). The social costs of carbon per ton CO_2e used in the SOFA 2023 report are \$51/tCO_2e (CHF 56/tCO_2), but there are updates from the US Environmental Protection Agency EPA with much higher estimates, e.g. at \$190.- per ton CO_2e (CHF 210/tCO_2e), thus almost four times as high as the value used in SOFA 2023 (see EPA (2023), page 101).[26]

In Switzerland, a thorough analysis of and debate on social costs of carbon values is undertaken in the context of estimates of the external costs of traffic. Recently, the social costs of carbon used there have been at about 140 CHF/tCO_2e (in 2020; about 127 US\$/ tCO_2e) based on avoidance costs approach (ARE, 2023a). Methodological updates were subsequently undertaken in 2024, in exchange with UBA Germany. Employing the impact model used by UBA and assuming some positive pure time preference rate (i.e. impacts on future generations are discounted at 1%) and equity weighting (damages in all countries are accounted for at high-income countries' prices) results in a central value

[26] With a PPP conversion factor of 1.105 (World Bank, 2024)

of 430 CHF/t CO_2 (decreasing to 130 CHF/t CO_2 without equity weighting and increasing to 1370 CHF/t CO_2 without discounting).[27]

Such a high value of 430 CHF/tCO_2e (US$ 390/tCO_2e) for the social costs of carbon would correspondingly strongly increase the relevance of the hidden costs of GHG emissions. Assuming a similar increase for all gases would thus result in a 7.7-fold increase in hidden costs, i.e. from 0.9 billion CHF to about 6.9 billion CHF (US$ 6.3 billion 2020 PPP), or, with the above-mentioned correction of the emissions by a factor 0.9, from 0.81 billion CHF to about 6.2 billion CHF (5.7 billion US$ 2020 PPP), thus changing its relative importance from next to negligible to a third of the original estimate or a fourth of the total estimate including this amended social costs of carbon values. It has to be emphasized that these cost estimates are only a very gross indication on how the values may change with higher social costs of carbon values, and that they are not derived on the basis of a full modelling context including uncertainty analysis as the original SOFA 2023 estimates are. In particular, these costs are not based on a gas-specific assessment with marginal costs being determined separately for CO_2, CH_4 and N_2O as done in the original SOFA 2023 estimate. This can also result in somewhat less intuitive dynamics, e.g. with increasing costs for CO_2 while those for CH_4 rather increase less, depending on the time dynamics of the impacts and damages assumed in the underlying model, also dependent on how these cost changes feedback to the underlying emission dynamics in the economic modelling (a central pattern being, for example, that marginal costs of CH_4 are higher in a context of high CO_2 concentrations than in one of low CO_2 concentrations, as the marginal impact is higher). One thus may rather expect a lower increase across all GHGs when weighting for the different dynamics of the different gases than above based on this factor for the CO_2 costs, thus a conservative assumption would be about half the increase, i.e. 3.1 billion CHF (US$ 2.9 billion 2020 PPP) rather than 6.2 billion CHF (US$ 5.7 billion).[28]

Summarizing, the hidden costs from agrifood-related GHG emissions will be amended by choosing 10% lower emission quantities and a higher social costs of carbon at CHF 430 per t CO2e to use the same value as the Swiss estimates of hidden costs of traffic. Literature would warrant to use even higher values (e.g. up to about CHF 1000/tCO_2e), but we keep to the lower value used by these traffic cost estimates. To account for potential overestimation due to climate model dynamics between different gases, we add a safety margin and reduce this value by 50%.

6.2.3 Nitrogen

For national nitrogen flows, detailed data is available from the Federal Statistical Office FSO on the agricultural nitrogen balance (FSO, 2023) and also from the work and data

[27] These correspond to US$ 390, 118 and 1240/ tCO_2e, respectively (Ecoplan/Infras 2024); cf. also the most recent estimate for social costs of carbon by Bilal & Känzig (2024), at US$ 1056/tCO_2e (CHF 1167/ tCO_2e).

[28] Choosing to account for about half the increase only is not based on data but just a general assumption for introducing some safety range regarding the overall effect on social costs of carbon may result from a corresponding increase in CO_2 costs.

in the context of the simulation model for ammonia emissions "Agrammon" (Agrammon, 2024). Ample information is also available in Switzerland's Informative Inventory Report 2023 (IIR) under the UNECE Convention on Long-range Transboundary Air Pollution (FOEN, 2023d) or, for nitrate, from (Hutchings et al., 2023). A general landing page for this and related information is the Emissions Information System EMIS of the Swiss government (FOEN, 2024a). There is also a report from the FOEN on nitrogen flows in Switzerland, FOEN (2013), and a more recent analysis of nitrogen flows in 2018 from the FOAG/Infras 2022 (Infras, 2022). Furthermore, the agro-environment indicators ("Agrarumweltindikatoren") AUI report the relevant numbers (Agrarbericht, 2023). The greenhouse gas inventory FOEN (2024c) is only covering those nitrogen flows of relevance for greenhouse gas emissions, thus not completely covering all flows such as nitrate or molecular nitrogen. Nevertheless, the GHG inventory provides a detailed basis for sources of nitrogen emissions, e.g. related to animal numbers, manure excretion and manure storage and management.

A first comparison of the data used in the SOFA 2023 report and from these specific Swiss sources indicates good consistency. In its response to a parliamentary interpellation, the Federal Council estimates that the external costs of nitrogen emissions (ammonia, nitrogen oxides, nitrous oxide, nitrate) for Switzerland - calculated using the European Nitrogen Assessment (ENA) approach (Brink et al., 2011) based on 2014 emissions - are in the range of CHF 0.86 billion to 4.3 billion per year (US$ 0.78 to 3.9 billion 2020 PPP)) (Bundesrat, 2016). Around 60 percent of this (particularly ammonia, nitrous oxide and nitrate) can be attributed to agriculture (Dümmler & Roten, 2018; Scnat, 2020), thus being compatible with the SOFA 2023 estimate of 2.9 billion CHF (2.6 billion US$ 2020 PPP) (which also uses the ENA numbers). Thereby, benefit transfer (cf. section 5.1) is central for the estimates of the hidden costs of nitrogen. Such benefit transfer is one source of considerable uncertainties in the estimates and it needs to be checked in detail how well this fits for a specific country (this benefit transfer is described in section 2.4 in the general background paper to SOFA 2023 and on page 35 in the background paper on Switzerland (Lord, 2023a, 2023b)).

In summary, the SOFA 2023 estimates for the hidden costs of nitrogen use are used without change (besides transforming from US$ PPP into CHF).[29]

6.2.4 Water use

This chapter focuses on the hidden costs of water use, particularly addressing water quantity rather than quality. These costs arise when water shortages occur due to unsustainable water use and reduced agricultural productivity. The decline in productivity also leads to a loss of supply of domestic agricultural products, which in turn leads to a loss of productivity in the area of human capital due to malnutrition or income losses in households not initially at risk of malnutrition. These issues ultimately reduce gross productivity. These costs of water use are covered in SOFA 2023. The controversial nature of counting these as hidden costs is discussed in section 3. Water quality is partly covered in the assessment of nitrogen pollution in section 6.2.3 and

[29] Using a PPP conversion factor of 1.105 (World Bank, 2024).

further addressed in potential amendments to the SOFA 2023 estimates in section 6.3. By differentiating the cost components according to their causes, costs related to water quality due to phosphorus, nitrogen and pesticides pollution are allocated to their causes and not to the water quantity. Due to lack of data, the costs of impaired ecosystem services (beyond agricultural production) due to reduced environmental water flows are not included (Lord, 2021b).

Climate change is altering the hydrological characteristics of Switzerland. Warming means that it snows less in winter but rains more, which means more electricity can be produced. In summer, however, there is a lack of meltwater, which reduces electricity production in summer. With the increasing heat in summer, plants are dependent on irrigation. The lack of meltwater leads to a water shortage in summer. The heavier rainfall caused by climate change leads to increased flooding. Biodiversity is jeopardised by the warming of water and water shortages in summer. All these supposed hidden costs are related to hydrology. However, the source lies in global warming, which is caused by the emission of greenhouse gases. Consequently, one could argue that these costs must be rather attributed to greenhouse gas emissions and not to water and should thus be covered in the social costs of carbon estimates (which they are).

Here, however, we are interested in water scarcity that is not related to climate change. Besides these climate change related costs from changed water dynamics that are included in the social costs of carbon estimates, SOFA 2023 reports costs directly related to water use (Lord, 2021b). In lack of specific marginal cost data for water scarcity in Switzerland, the estimates from SOFA 2023 are used here as well. The AQUASTAT water consumption used in the SOFA 2023 report only includes blue water consumption in agriculture, which amounts to 160 million m^3. According to national studies, water consumption in agriculture is around 400 million m^3, most of which is drawn from spring water and surface water. Artificial meadows, permanent grassland, vegetables and strawberries account for over 50% of irrigated areas. The food industry uses just over 50 million m^3 of water. Given that irrigation water use is most relevant here regarding hidden costs, and national studies largely confirm this number used in SOFA 2023 (Eisenring et al., 2021), no refinement of these numbers is required and the cost remains at CHF 1.3 million (1.2 million US$). Compared to the total CHF 21.1 billion (19.1 billion US$) of hidden costs reported in SOFA 2023 (accounting for the adjusted health costs as described above in section 6.2.1), the effect remains negligible. These low costs indicate that water scarcity is currently not an issue in Switzerland and this water use is not (yet) very unsustainable. Due to more extreme weather events, there will be regional shortages or oversupply, but the water supply is expected to be secured in the long term over the year (cf. below). Groundwater pollution from agriculture and industry poses a far greater risk in the near future, but this is partly accounted for in other impact categories in the SOFA 2023 assessment (nitrogen, cf. above) and partly taken up in section 6.3 on additional topics of potential interest.

Although Switzerland only covers 0.4 percent of Europe's surface area, it accounts for around 5 percent of Europe's water reserves. The total volume of groundwater in Switzerland's subsurface is around 150 billion m^3 (FOEN, 2019b). The volume of water that can be extracted from the subsurface without triggering conflict to sustainability targets amount to about 18 billion m^3 of usable groundwater. Not only are there extraordinarily large reserves of water on the territory of Switzerland, these are also constantly replenished by large amounts of precipitation (around 60 billion m^3 per year) (scnat, 2024). Around 1.3 billion m^3 of drinking water is extracted from groundwater every year, which accounts for around 80 % of the total public drinking water supply in Switzerland (FOEN, 2019b). Switzerland's water resources, including groundwater resources, will only change slightly overall in the future. However, local to regional bottlenecks in the water supply could occur as a result of shifts in the seasonal distribution of precipitation and runoff (FOEN, 2021). Without climate protection, the amount of water available in water bodies will fall sharply in summer and there will be more periods of drought and thus regional and temporary water shortages, in a context, where irrigation demand from agriculture increases (Lanz et al., 2021). Climate change is increasing the pressure on water ecosystems, which are already severely affected by high water temperatures and low or even absent runoff, thus jeopardizing the indispensable services they provide (Bundesrat, 2021; FOEN, 2021). Thus, a thorough assessment of potential future water scarcity and its seasonal patterns, irrigation needs in agriculture and related potentially hidden costs, as well as strategies to deal with these challenges is needed and activities to collect and assess this information are underway, e.g. in the context of the project "Swiss Irrigation Info" (HAFL, 2023) and other projects (Agroscope, 2024c; BFH, 2023; Brunner et al., 2019; Eisenring et al., 2021).

Albeit not (yet) an issue of central national importance, Switzerland contributes to global water scarcity by importing goods that require considerable quantities of water in their production. Some of these imports come from regions of the world where water scarcity is severe, and therefore imports into Switzerland make a contribution. In contrast to the currently almost negligible national values related to water scarcity impacts, "imported" water scarcity values are significant and amount to about 60 billion m^3 of water equivalents (a measure accounting for water scarcity, hence not identical to physical water volumes). The main sources in terms of these imported embedded water quantities are imports of cotton, oranges, tomatoes, almonds, cereals and wine (Nathani et al., 2022). Hidden costs related to imports are taken up in section 6.3.8.

Summarizing, the original estimate of 1.3 million CHF (1.2 million US$) is used. While this currently is negligible in comparison to the total hidden costs, water use and scarcity may gain much more relevance in the future due to climate change, and hence it is warranted to make this visible and monitor closely. This is in particular important as the cost estimates used here are incomplete, covering productivity losses only and not including impaired other ecosystem services due to water scarcity. For costs due to water pollution see 6.3.4.

6.2.5 Poverty

SOFA report defines moderate poverty as income below the international poverty line of US$ 3.65 2017 PPP, with a PPP conversion factor of 1.188 for 2017, corresponding to about CHF 4.34 (World Bank, 2024). On this basis, in SOFA 2023, the related hidden costs for Switzerland are estimated to be zero.

However, for Switzerland, a different reference point may be used, given that the named poverty line above is very low for the Swiss context. The "Richtlinien der Konferenz für Sozialhilfe" (SKOS) define the poverty line as an annual income of CHF 27’500 for a single person and 48’000 for families with two children. This minimum income does not include expenses for health insurance, social security contributions and taxes, which is why these must also be added. According to SKOS, roughly estimated a further 20% can be added, giving a poverty line of between 33’360 and 57’600 (SKOS, 2020). The average agricultural income in 2021 was CHF 59’800 per family worker and CHF 80’700 per farm. The agricultural income per family member varies depending on the agricultural region. In the planes (“Talgebiet”), the average agricultural income per family worker and year is CHF 76’600, in the hill region CHF 54’600 and in the mountain region CHF 43’100, and CHF 99’900, 73’100, and 61’100 per farm. Farmers earn additional money from outside agricultural activities, on average amounting to CHF 34’500 per farm, resulting in a total farm income of CHF 111’300, still with considerably differences between the regions, namely CHF 129’200 in the planes, CHF 106’000 in the hill region and CHF 91’800 in the mountain region (Jan et al., 2022).

These numbers thus support the findings from SOFA 2023 that hidden costs from low wages – if measured in relation to the poverty line are low or zero. This does however by far not cover all aspects of farmers’ and farm laborers’ livelihoods, as e.g. no information on hourly wages can be derived and no information on employed agricultural workers such as harvesters is included. For example, there are indications that psychological stress and overload for farmers have increased recently, potentially resulting in productivity losses (Schweizer Bauer, 2023). For the farm workers, the recommended wages are rather low, but still above the poverty line (CHF 40’620 per capita and year), with high labour time of 52.25 hours per week, which then results in low hourly wages (Agrimpuls, 2022) that are often considerably below minimal wages. Investigations indicate harsh labour conditions in the field, partly high accommodation costs and very low hourly wages (SWI, 2022). This situation can be very unfair, and there are arguments to deem this unacceptable on moral grounds; others, however, argue that even if paid poorly, these (often migrant) workers may still be better off working as harvesters in Switzerland than if they were working in their home countries. In this context, some also criticize that this situation of distributional inequality – be it as unfair as it is – does not entail any hidden costs, but reflects the distributional issues and inequalities that can come with market solutions, cf. section 3.

Thus, albeit not easily quantifiable, the hidden costs of the agrifood systems regarding poverty are clearly an issue and setting them at zero is likely overly optimistic. This is also supported by the numbers of Perotti (2020) who estimates hidden costs due to distributional failure at CHF 0.49 billion (US$ 0.44 billion 2020 PPP). Her estimate is based on unpaid labour mainly provided by women in agriculture, i.e. capturing a somewhat different aspect than SOFA 2023.

In summary, no changes from the SOFA 2023 estimates that amount to zero are implemented. However, it needs to be highlighted that this is an important topic and needs to be monitored closely, as there is also a danger of underestimating the impacts and relevance of low wages.

6.2.6 Under- and malnourishment

Hidden costs due to under- and malnourishment in SOFA 2023 are based on protein-energy malnutrition, thus clearly addressing the issue of lack of food in the sense of sufficient protein and energy supply. For Switzerland, they are negligible (Lord, 2023b). For completeness, we consider the original Global Burden of Disease data (GBD, 2019), where we assess the data for protein-energy malnutrition and also for iron deficiency, the next most important category of under- or malnutrition, which was also named as a potentially important category to be included in Lord (2023b). The allocation of iron-deficiency to the category of under- and malnutrition rather than to the dietary health costs is not so clear-cut as with the undersupply of protein and calories. Being a clear undersupply of a specific nutrient, it can however well be attributed to this category rather than to the broader health category related to dietary patterns that are rather assessed on commodity level (e.g. low intake of fruits and vegetables, etc., cf. section 6.2.1 above), but it would also be legitimate to attribute it there. In the end, we decided to add it to this category here, i.e. to under- and malnourishment. The data from the Global Burden of Disease study shows that 2'774 DALYs are attributable to protein-energy deficiency and 3'381 DALYs are assignable to iron deficiency. Multiplied with marginal costs of about 93'000 CHF per DALY (US$ 84'000) this results in roughly 0.57 billion CHF (US$ 0.52 billion 2020 PPP). This is a comparatively small but not negligible amount.

Summarizing, the costs from protein-energy malnutrition are recalculated and those from iron deficiency are added to arrive at a refined estimate of hidden costs related to undernourishment (amounting to about 0.57 billion CHF; 0.52 billion US$ 2020 PPP).

6.2.7 Land Use Change

Hidden costs related to land use change refer to the related loss of ecosystem services. The baseline to which this is compared in the SOFA 2023 estimates is the natural ecosystem. Any monetary aspects of land scarcity, ideally captured in land prices, are not addressed here, assuming that these are not hidden. The total time-integrated damage costs per hectare used in SOFA 2023 amount to about US$ 25'000 and 100'000 per hectare for the loss of unmanaged grassland and forests, respectively (CHF 28'000 and 110'000/ha, respectively). These are the two biomes covered by the data for Switzerland[30]. Multiplying these costs with the respective areas for land use change on these two biomes and then summing up, this results in a net total of about 0.22 billion CHF (0.2 billion US$).

These numbers are very uncertain and the cost estimates used in the previous paragraph are not based on specific values for Switzerland but rather taken from similar country contexts. Some studies attempting the valuation of ecosystem services specifically for

[30] Based on the detailed data used in the SOFA 2023 calculations provided by Steven Lord on request.

Switzerland do exist. Buser et al. (2020), for example, provide concrete values for a number of specific cases. Comparability is partly difficult, but some comparison is possible when using the numbers provided in the more detailed study ARE (2005), where Buser et al. (2020) base their estimates on. There, damage costs based on restoration costs per hectare are provided, resulting in values that are more than an order of magnitude higher for grasslands and forests (average values per hectare and year, for a time horizon of 30 years, in CHF in the year 2000: 14'400 and 19'000; thus, the inflation since 2000 also needs to be accounted for).

Given these difficulties in comparisons, the high uncertainty level of these numbers, and the relatively low importance of land use change within the SOFA 2023 estimates in relation to the other cost categories, the potential for double counting when adding the costs of biodiversity losses, as suggested in section 6.3.3, makes refinement difficult, but also not of most central importance. If putting a number to the hidden costs of land use change, it may rather be at about 2.5 billion CHF, i.e. an order of magnitude higher than reported in SOFA 2023. In any case, it has to be emphasized that loss of ecosystems and habitats due to land use change should be avoided wherever possible and closely monitored. In Switzerland, such monitoring is available for many contexts, e.g. via WSL (2024).

Summarising, albeit the number may be considerably higher than reported in SOFA 2023, the number from SOFA 2023 is taken without changes, due to the high uncertainties and the potential of double counting with the biodiversity estimates added in this refinement.

6.3 Additional topics and complements to the estimates of hidden costs

A number of additional costs should be addressed and maybe covered for the Swiss case study, if assumingly relevant and if possible. In particular, there will be expectations from the public that certain aspects are covered in the cost estimates, as they play an important role in the national debates on sustainable food and agriculture (cf. section 6.1). Examples are the use of plant protection chemicals, biodiversity loss, loss of ecosystem services, antibiotics use and resistance, animal welfare, soil fertility/soil loss/erosion and phosphorus surplus, as well as water protection and water use for irrigation in a context of future water scarcity, which is an emerging topic in the context of climate change impacts and adaptation. If these indicators cannot be covered, it is important to explicitly explain why this is not possible, to manage expectations from the public towards the costs covered in this assessment.

We shortly copy the new topics as identified in section 6.1 and subsequently address each of them in more detail, analysing if and how they could be included and which results arise from inclusion, if such is undertaken:

- Phosphorus surplus
- Soil health, soil fertility, soil quality (there, work in the context of the "Bodenindexpunkte" (sanu, 2024) may be helpful); drained organic soils and their soil organic carbon losses

- Biodiversity/ecosystem state and loss (various types of indicators, species, habitats, etc.)
- Use and impacts of plant protection chemicals, in particular human health costs
- Antibiotics use and antibiotics resistances and related human health costs
- Animal welfare

6.3.1 Phosphorus surplus

Phosphorus and reactive nitrogen in waterways have a joint impact on ecosystem services. This makes it difficult to attribute the related costs to nitrogen and phosphorous individually. The European nitrogen assessment, on which the SOFA 2023 nitrogen costs are based, accounts for costs of eutrophication and biodiversity loss. Nitrogen costs thus may already capture current damages from phosphorus loading largely due to run-off from agriculture.

Given nitrogen-related costs are reported, there may be no need to add the phosphorous impact category separately (cf. also the paragraphs on phosphorus in the discussion section of the Swiss background paper Lord (2023b)). Phosphorus in Switzerland is mainly problematic in the accumulation in lakes and less so in soils. Phosphorus in lakes is a main contributor to eutrophication of waterbodies which removes oxygen from the water and harms the aquatic biodiversity. The problem appears regional in catchment areas with intensive livestock production (FOEN, 2008). Most known in the Swiss national context is the situation of the Lake Sempach and Lake Baldegg, where phosphorus oversupply from livestock operations resulted in eutrophication. The situation improved somewhat over the past decades, but the lakes are still poor in oxygen and need continuous aeration to avoid water quality deterioration. The impacts of phosphorus are largely regional and it may be overly specific/complex to quantify in relation to what it may add to a national assessment (Scherer & Pfister, 2015). Available studies indicate that the situation regarding P surplus or deficits in soils remains rather stable and that the soils with the highest oversupply rather decrease than increase (Agrarbericht, 2022). Problems related to P thus persist, but do not seem to be increasing.

From 2026 onwards, the obligation to notify the trade of plant protection products and the trade in nutrients will apply in Switzerland (FOAG, 2024a).[31] The data will be used for agri-environmental monitoring (Agroscope, 2024a) and the risks to semi-natural habitats and groundwater will be calculated. This data provides detailed national impact quantities for the use of nitrogen, phosphorus and plant protection chemicals and could be used to calculate hidden costs, if corresponding marginal cost rates can be made available.

In sum, given this situation of spatial heterogeneity and dynamic complexity of phosphorus impacts, as well as the (partial) coverage by nitrogen and a non-increasing

[31] Originally, digiFLUX also aimed at reporting the application of plant protection products on farm and plot level, but this may not be implemented in the end (Mitteilungspflicht Pflanzenschutzmittel und Nährstoffe (digiflux.info)).

problem development, we refrain from specifically quantifying the hidden costs related to P use in Switzerland. Nevertheless, this topic must not be lost and when addressing leverage points as inspired by these TCA assessments (cf. section 7), P will be addressed together with N in the context of reducing nutrient oversupply.

6.3.2 Soil health, soil fertility, soil quality

Soil health and soil fertility are an important topic of policy debates on the environmental impacts of agriculture. There is currently no data applicable in this context on impact quantities or external costs from agricultural management relating to soil erosion, soil degradation or soil fertility for Switzerland, though.

One possible approach would be to estimate soil fertility and potential losses thereof on the basis of agricultural intensity. There is data on the acreage and intensity of individual crops. The use of mineral fertilizers, pesticides, farmyard manure, and from other inputs and outputs/yields can be estimated for each crop and intensity (Gubler et al., 2022). Further information on soil quality, etc. is available from the "Bodenindexpunkte" (sanu, 2024) or projects in the context of the National Research Programme NRP68 on "Soils as a Resource" (Charles et al., 2018). In the latter, soil compaction was investigated as one impact category of relevance on many agricultural soils in Switzerland, finding that yield losses due to compaction can be considerable: in the first year after a compaction event, yields drop by 20-80%; depending on the regeneration measures taken, this impact is reduced over a certain time.

Perotti (2020) calculates the external costs related to soil erosion on the basis of topsoil losses of soil organic carbon (SOC), amounting to about 0.4 tons carbon lost per hectare and year. These rates are influenced by carbon inputs to soils (harvest residues and organic fertilizers), soil management, soil cover and initial SOC stocks. Multiplying this with the cropland area (without temporary grasslands), i.e. about 276'000 ha) results in about 110'000 tons C or 400'000 tons CO_2e lost per year (in case one assumes that the carbon lost via erosion is ultimately emitted as CO_2 to the atmosphere, which likely is an overestimation). This is then priced with hidden costs of soil quality and soil fertility loss, assumed CHF 0.03/kg SOC lost (Perotti, 2020), thus resulting in total costs of 0.003 billion CHF (US$ 0.003 billion). In addition, the related potential emissions are priced with a carbon price of CHF 430/tCO_2e (cf. section 6.2.2), resulting in additional costs of about 0.17 billion CHF (0.19 billion US$). In total, these SOC losses thus lead to costs of up to 0.173 billion CHF (0.193 billion US$). Importantly, the number for hidden costs of soil quality and soil fertility loss is rather an underestimation as it is based on correlations of SOC and yields as assessed in Ligthart and van Harmelen (2019), not accounting for any other aspects of soil quality and soil fertility loss, e.g. related to other ecosystem services or biodiversity. Albeit the estimate here is relatively small, this thus should not result in soil fertility losses becoming neglected in comparison to other hidden costs.

In sum, the cost estimates from soil carbon losses are added to the hidden cost estimates, resulting in an additional cost of about 0.17 billion CHF (0.19 billion US$).

6.3.3 Biodiversity

In SOFA 2023, biodiversity is covered as part of the land use change and nitrogen emissions category. The resulting values are low for Switzerland, given that the significant part of nitrogen emissions relates to NH_3 emissions to air, which includes the hidden costs of health impacts. This contrasts with the public perception and also the scientific debates on the importance of biodiversity and its losses. It would thus be helpful to report biodiversity separately, which is however difficult in the context of the SOFA 2023 calculations, as this would require splitting the land use and nitrogen emissions categories in the biodiversity related and other aspects, plus adding further impact categories related to biodiversity loss that are not yet covered, duly accounting for potential double counting of impacts and costs. Such an approach would be very complex and subject to large uncertainties.

We thus decided to take a different route, referring to independent estimates of the hidden costs of biodiversity losses in Switzerland, which cover biodiversity consistently (albeit still with large uncertainties), at the costs of the estimates not being fully compatible with SOFA 2023, as they result in some double counting when added (namely for the part of biodiversity impacts from nitrogen use and land use). However, we think this is nevertheless warranted given the additional cost category being covered explicitly by this and thus made visible. Furthermore, the values reported in SOFA 2023 are more than an order of magnitude lower than the estimates derived below[32], thus indicating that this specific double counting is not very relevant.

Dümmler and Roten (2018) provide such estimates and arrive at CHF 4.9 billion in hidden costs of agriculture related to impacts on biodiversity in Switzerland in the year 2016. For this estimation, they acknowledge that it is very difficult to monetise the loss of biodiversity and ecosystem services, as the disappearance of individual animal and plant species also means an enormous loss of cultural value. Therefore, only very approximate values can be given. Dümmler and Roten (2018) refer to calculations done by the Federal Office for the Environment - on the basis of some EU study - which estimate the annual costs of biodiversity losses. These estimates are done via the costs incurred to compensate the ecosystem services that are lost as a consequence of the biodiversity losses. The result lies at around four percent of GDP by 2050.[33] With a GDP of about CHF 660 billion in 2016 and the assumption that the costs of biodiversity loss in 2016 will amount to three percent of GDP and that a quarter of this will be incurred in agriculture, the above number of CHF 4.9 billion is derived. Perotti (2020) follows a similar route, but updating some assumptions behind these numbers, mainly addressing indications of underestimation in the shares of GDP adopted for the biodiversity losses

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[32] LUC amounts to 0.22 billion CHF (0.2 billion US$) and non-health related aspects of nitrogen emissions amount to 0.27 billion CHF (0.24 billion US$), while the biodiversity cost estimate derived below amounts to about 7.5 billion CHF (6.8 billion US$).

[33] Regrettably, Dümmler and Roten (2018) do not provide further details to trace back these studies and the corresponding numbers used here. Some details can however be found in FOEN (2017), EC (2015), and EEA (2015).

and the share attributable to agriculture and the food system, then arriving at roughly the double estimate of CHF 10.3 billion. Ecoplan/Infras (2014) provides cost estimates for biodiversity losses related to air pollution and habitat loss, which we do not discuss here further, as these categories are already captured separately in the previous sub-sections 6.2.3 and 6.2.7.[34]

Summarising, hidden costs of biodiversity loss are particularly uncertain and amount to 5 – 10 billion CHF (4.5 – 9 billion US$ 2020 PPP) and we choose the middle value of 7.5 billion CHF (6.8 billion US$) to be used for complementing the SOFA 2023 estimates. Core assumptions behind these numbers are the share attributed to agriculture and the correlation between GDP and biodiversity loss till 2050.[35]

6.3.4 Plant protection chemicals, ecosystem impacts and human health

As with biodiversity, it is expected in Switzerland that plant protection chemicals are addressed explicitly in any assessment of hidden costs in agriculture. Chemicals for plant protection have diverse impacts on human health, ecosystems and biodiversity. This begins with the application, where emissions from plant protection products can cause health issues for the laborers and residents. After application, these chemicals and various decomposition products can be found in air, soil and water, as well as partly in the harvested good itself. Health impact can occur via inhalation of chemicals due to air pollution, via water pollution and exposure in food. Residues of these chemicals affect ecosystem services and threaten biodiversity (EEA – European Environment Agency, 2023).

To include the hidden costs of plant protection chemicals, both the health and the ecosystem/biodiversity impacts need to be monetized. Health impacts can be captured via the calculation of the related productivity losses due to pesticide exposure. This can be done in the same manner as for the hidden costs of unhealthy diets, i.e. by quantifying DALYs related to pesticide exposure (Li, 2018).

Second, ecosystem service and biodiversity losses can be estimated by quantifying the amount of chemicals used times the corresponding marginal costs, taking into account the differences in toxicity between different active substances. Importantly, the choice of application technique contributes significantly to the effectiveness of the application and the amount of pollutant released into the environment. However, such effects usually cannot be considered in the cost estimates due to lack of data.

SOFA 2023 does not contain calculations on external costs caused by the use of pesticides and other plant protection chemicals. Perotti (2020) analyses these costs and distinguishes between the health consequences due to consumption of treated products and the exposure to pesticides in food production. The latter was not quantified as it was

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[34] This is a very generic assessment of the costs related to biodiversity loss. For details on the roles of the various relevant aspects such as species, habitat and genetic diversity loss in these estimates, the original publications used in these studies need to be consulted.

[35] Cf. explanations above, this is based on the approach and numbers used in Dümmler and Roten (2018).

assumed to be negligible in the Swiss context.[36] National costs for pesticide health impact were estimated at about CHF 50 million (45 million US$), i.e. a relatively low value compared to other cost categories. However, such quantification is viewed very critically. According to the Federal Office of Public Health and the Federal Food Safety and Veterinary Office, there is no quantitative information on pesticide exposure in food, and it is assumed that since there is no (sufficiently) proven link between the consumption of food with pesticide residues and health damage, it would also be difficult to quantify any health costs that could be regarded as external costs of pesticide use, cf. also Baudry et al. (2023). In order to be able to determine these costs in the future, consideration should be given to linking these costs to changes in quantities applied and their toxicity, which could be done on the basis of the available data on plant protection chemicals sales volumes and water quality (FOAG, 2024b; FOEN, 2019a, 2023b, 2024b). The database provided by Fantke and Jolliet (2016) can be helpful for such quantifications. It provides information on many pesticide-crop combinations regarding uptake and exposure level for consumers, as well as potentially related health impacts.

Ecosystem and biodiversity impacts from the use of plant protection chemicals are not quantified specifically, as these costs are already covered in the biodiversity cost assessment provided by Perotti (2020), cf. section 6.3.3.

A very different approach to arrive at estimates of hidden costs of plant protection products is offered by Schläpfer (2020). He bases his estimate on an analysis of the monetary compensation for agri-environmental measures to reduce the use pesticides. The payments follow a compensatory approach for reduced yields (i.e. reflecting rather a willingness-to-accept (lower yields) approach than a damage cost (of pesticide use) approach[37]). The corresponding payments amount to CHF 700 per ha for herbicides and for fungicide and insecticide to around CHF 400 per ha. Accounting for area shares with such plant protection chemicals application based on total agricultural area and the shares of organic or otherwise chemical plant protection free production, Schläpfer arrives at an estimate of about CHF 0.27 billion (0.25 billion US$) for the hidden costs associated with pesticides. In principle, this assessment covers both the health and biodiversity impacts, but it is in the nature of the approach that it rather illustrates that payments for reducing plant protection chemicals seems considerably lower than a social optimum linked to damage costs and their avoidance would suggest.

In summary, it would be very challenging to provide good updated estimates of the health impacts of pesticide exposure, hence we suggest to not add it to the current assessment. But it must be taken into account in future assessments. Importantly, the impact on biodiversity is captured in the costs of biodiversity loss as suggested above. In as much as pesticide affects water quality, this is captured in terms of biodiversity

[36] Perotti (2020) makes this assumption based on the similar judgment in the study she bases her analysis on (Zandonella et al., 2014). These authors state that the high Swiss regulatory standards minimize these costs of pesticide applications.

[37] Another approach in this spirit would be to estimate the hidden costs on the basis of costs for water treatment to remove pesticide residues incurred by the water companies.

impacts, however not in terms of health impacts or the associated increased costs of water treatment to avoid such impacts. In any case, the monitoring of pesticide use rates and which active ingredients are applied is crucial in order to be able to react in case related hidden costs may change.[38]

6.3.5 Antimicrobial resistance

Increasing antimicrobial resistance has been observed in the past. As a result of this resistance, the effectiveness of antibiotics is diminished and the health care system is weakened. This issue has been increasingly focused on in the recent past and monitoring and investigating resistance forms is a new core topic in research. The reasons for the growing resistance are the widespread and improper use of antibiotics in the health care system and in livestock production. In intensive livestock production, where many animals are kept in limited space, antibiotics are often used. This is done to prevent disease, promote growth and deal with husbandry-related problems. This practice is intended to prevent the outbreak of disease, accelerate growth and alleviate health problems caused by confinement and stress. The widespread use of antibiotics allows bacteria to adapt and develop resistance.

The hidden costs of antimicrobial resistance can be seen in the form of productivity losses. The resistance of bacteria to antibiotics worsens the effect of the medicine and leads to health problems. In economic terms, increasing resistance has an impact on the productivity of each individual. The loss can be expressed in terms of DALY. DALY corresponds in this case to "lost" years due to resistance. The marginal costs are derived from the average productivity per capita.

On a global basis, the "Institute for Health Metrics and Evaluation (IHME)" collects data for the Global Burden of Disease database and calculates DALY due to antimicrobial resistance. This information is available for each country. In 2019, there were 563 deaths attributable to antimicrobial resistance and 2'600 deaths associated with it in Switzerland (IHME, 2023). In order to calculate the hidden costs of Swiss agriculture and food system, it should be clear which part of the DALYs can be attributed to the agrifood system, which is difficult.

There are various national and international efforts to monitor antimicrobial resistance, e.g. ANRESIS (2024), EC (2017), FAO (2024c;), NARA (2024), NRP72 (2023), OECD (2018) or ZOBA (2024). With the Swiss National Strategy on Antibiotic Resistance (StAR) (StAR, 2024b), the four federal offices FOPH, FSVO, FOAG and FOEN are pursuing the common goal to combat antimicrobial resistance in a cross-sectoral manner and in collaboration with the relevant stakeholders. This One Health approach is crucial to ensure that antibiotics continue to be effective. The One Health Action Plan 2024-27 of the StAR, being developed with various partners and stakeholders from research,

[38] Such changes can apply to all impact categories, also related to health aspects of pesticide use of farmers and farm workers, currently deemed negligible (cf. above): see e.g. the recent decision of the German Federal Ministry of Labour and Social Affairs, to list the «Parkinson-syndrome from pesticides» as a recognized occupational disease (BMAS, 2024).

politics and industry, has been published recently in June 2024 (StAR, 2024a). The aim of this action plan is to effectively combat the "silent pandemic" of antibiotic resistance and to consistently implement the One Health approach required for this.

The "Swiss Antibiotic Resistance Report" (SARR) (StAR, 2022) is the national report on the situation of antibiotic resistance in Switzerland. The report focuses not only on antibiotic consumption and resistance in human and veterinary medicine, but also on the effects in the environment (One Health approach). It shows, for example, that from the antibiotics used in the livestock sector, 79 percent is for cattle and 14 percent for pigs. In addition, the Federal Food Safety and Veterinary Office publishes the annual ARCH-Vet report on antibiotic sales and resistances (StAR, 2023) and the IS-ABV report on antibiotics use for animals (BLV, 2022).

Gasser et al. (2019) estimated that 7156 cases of infections with antibiotic resistant bacteria occurred in 2015 in Switzerland, which accounted for 276 attributable deaths and 7400 DALYs. Using the marginal costs for burden of diseases factor provided for DALYs in SOFA 2023 (Lord, 2023b), about 93'000 CHF per DALY,[39] this results in an antimicrobial resistance-related cost of roughly 700 Mio CHF per year. Similar amounts are also expected in the future (StAR, 2024a). Based on the assumption that 22% of antimicrobial resistance is attributable to the agrifood system (Perotti, 2020)[40], this results in a cost of about 0.15 billion CHF (0.14 billion US$).

In sum, we thus add the antimicrobial resistance hidden cost estimate of 0.15 billion CHF (0.14 billion US$) to the hidden cost assessment. This is much smaller than other impact categories, but it may become more relevant in the future and close monitoring is surely warranted.

6.3.6 Animal welfare

Hidden costs related to animal welfare deficits, animal health or prevention of zoonoses are not covered in SOFA 2023. Some approaches to estimate such exist. Vissers et al. (2023), for example, suggest a method to estimate animal welfare costs in terms of avoidance costs, i.e. by the costs of implementing infrastructure and other measures that allow to increase the observed animal welfare level to a pre-set optimal level (which are then however not hidden in the sense that they are not relevant for production decisions, as these infrastructure and other costs are taken into account in decisions). Hidden costs related to animal health deficits could be estimated via veterinary costs. Where, however, those may not be deemed “hidden”, given that they arise in a market context. For zoonoses, no specific information is available for Switzerland and which part of these may potentially be attributed to agriculture, albeit it is clear that the related costs can be significant (Bundesrat, 2023).

Perotti (2020) provides values for the hidden costs related to animal welfare deficits. She uses estimates from Schläpfer (2020), based on this approach of welfare deficit avoidance

[39] With a PPP conversion factor of 1.105 (World Bank, 2024)

[40] This percentage is based on Fitzpatrick et al. (2019), which refer to estimates from the US from 2013 (CDC, 2013).

costs described above, arriving at a minimum of CHF 0.11 billion (0.1 billion US$ 2020 PPP) in related hidden costs (covering the payments for two animal welfare programs in Switzerland, BTS for animal-friendly housing and RAUS for additional outdoor space).

In sum, we suggest to add this cost estimate of 0.11 billion CHF (0.1 billion US$) to the hidden cost assessment. For Switzerland, these costs are relatively small compared to the other cost categories, but the avoidance costs may not take into account all issues involved in relation to animal suffering. This cost category should not be neglected and in case other countries base an assessment on this case study work for Switzerland, they may be of much higher relevance, given lower animal welfare standards in many countries.

6.3.7 Economic costs related to subsidies and other incentives

Some discussion arose in the monitoring group to this project, whether economic costs related to subsidies and other incentives with partly adverse effects should also count as hidden costs of the agri-food system or not – without arriving at a final conclusion. An encompassing assessment and discussion of these aspects and potential related hidden costs is provided in Dümmler and Roten (2018). We address this in more detail in section 6.4.2. Here, we just report that some share of cost categories summing to about CHF 12.6 billion (11.4 billion US$ 2020 PPP) may be addressed as hidden costs. These costs consist in direct payments, investments in research, monitoring, etc. (4.3 billion CHF; 3.9 billion US$), higher consumer prices due to border protection (4 billion CHF; 3.6 billion US$), foregone income due to lack of free trade agreements (3.1 billion CHF; 2.8 billion US$) and the costs of various agricultural privileges such as tax reductions and investment support (1.2 billion CHF; 1.1 billion US$). It is important to note, that many of the instruments and structures behind these costs (e.g. investments in research and monitoring, and many subsidies for public good provision, etc.) make much sense and should not be abandoned. Others support or encourage producers/drivers of hidden costs (e.g. steering consumption preferences, supporting unsustainable farming practices) and are therefore to be reformed (cf. e.g. the discussion of biodiversity damaging subsidies in Gubler et al. (2020a)). Hence, only an (unknown) share of these 12.6 billion CHF (11.4 billion US$ 2020 PPP) may count as hidden costs; identifying the size of this share would thus be important to further investigate actions on these cost categories.

These costs are of a different nature than the other costs reported here, as they are monetary, referring to real payment flows, and not referring to damage or avoidance costs of primarily physical impacts. In consequence, these costs are not subject to potential double counting with the other categories. Clearly, part of these costs can result in costs in other categories, e.g. in case some subsidy (counted here) results in biodiversity loss (counted in the biodiversity loss cost category). However, awareness of both the costs of the subsidy and the damage costs of biodiversity loss is needed, as they do not double count the same costs.

Due to their particular character, and the fact that they are rather not deemed to be hidden costs as the other cost categories are, these costs are reported separately and qualitatively only in the compilation of the results in section 6.4.1 and are not added to the other costs. In any case, only a share of these costs would have to be added as hidden costs, as part of them clearly contribute to welfare, as elaborated above.

6.3.8 Hidden costs related to imports

In this section, we address hidden costs related to imports. Here, we focus on hidden costs in the countries of origin related to the production of food and feed imports, as well as imports of most relevant other production inputs not produced from agriculture, such as mineral fertilizers or pesticides. We do however not address imports of non-food or-feed agricultural commodities such as cotton or, derived from this, clothes.

We assume that the hidden costs related to the production of the imported goods mainly arise from the same categories as covered in the refined assessment of the SOFA 2023 estimates. We also focus on the key topics only, where larger cost values are to be expected. These are biodiversity loss, land use (e.g. deforestation), water use (in water scarce environments), nitrogen use and GHG emissions (including transport emissions). Furthermore, poverty of farmers and agricultural workers needs to be addressed as well.

Covering the hidden costs of imports is not consistent with the choice of system boundaries in SOFA 2023 (cf. section 5.1). It is however an important additional information to the hidden cost estimates from SOFA 2023 and their role in agrifood system transformation, in particular in Switzerland, which has a high share of imported agricultural goods and which imports all mineral nitrogen fertilizer. Furthermore, it was a clear expectation from the monitoring group, that some (gross) estimate of the hidden costs of imports should be provided.

To consistently calculate the hidden costs of imports, the imported quantities and the countries of origin need to be identified first. Subsequently, the related impacts could be derived based on lifecycle analysis (LCA) and impact data (on nitrogen and water use, GHG production and transport emissions, land use impacts, labour and related poverty impacts per ton product). This could then be multiplied with the respective marginal costs from SOFA 2023. In addition, some overall estimate for biodiversity impacts would need to be derived. Coverage should include the most important goods, either in volume (e.g. cereals) or in value (to cover cash-crops that likely are produced rather intensively with potential high impacts, e.g. coffee, cacao, fruits and vegetables). For mineral fertilizers and pesticides, the production quantities and related GHG emissions would need to be identified, plus the transport emissions.

However, we decided to do some simplified estimation only, focusing on the key categories biodiversity, GHG emissions and water scarcity, as these assumingly cover a large share of costs of imports and as a first gross estimate of them can be derived relatively easy with the help of other studies, as detailed in the following paragraphs.

For Switzerland, estimates of costs caused by imported food and feed are provided in Furrer et al. (2021). This report indicates[41] that GHG emissions from imports amount to about 30% of domestic emissions related to agriculture and food; biodiversity impacts of imports amount to about 50% (potentially disappeared fraction of species) to 100% (freshwater eco-toxicity) of domestic impacts (we thus assume the middle of 75% for biodiversity); water scarcity impacts of imports amount to three times the domestic impacts.

We then use these factors (30% for GHG emissions, 75% for biodiversity, 300% for water scarcity) to derive the hidden costs of imports, by multiplying with the hidden cost estimates for the corresponding domestic impacts. This results in 6.68 billion CHF (6.1 billion US$ 2020 PPP).[42] For the GHG emissions as a global pollutant, this is appropriate; for biodiversity and water scarcity, however, local marginal costs from the import countries should be used instead of the Swiss marginal cost values as implicitly used when proceeding as described. This will be particularly relevant for marginal costs of biodiversity impacts (e.g. related to deforestation of primary tropical forests) and of livelihood and poverty-related impacts. For a first gross estimate, this approach just described may be legitimate, but it should definitely be refined in the future.

To these estimates of hidden costs of imported food and feed, we add the hidden costs from GHG emissions from the production of imported mineral fertilizers. We use the mineral fertilizer quantity of about 40'000 tons, as reported in (OECD, 2024), the composition of about 50% ammonia nitrate and 50% others, mainly urea (Hofer, 2022) and an emission factor based on these weights of about 4.5 tons of CO_2e/ton nitrogen (Walling & Vaneeckhaute, 2020). This results in about 0.18 million tons of CO_2e, or costs of about 40 million CHF (applying a social costs of carbon value of CHF 430/tCO_2e and a correction factor of 50%, cf. 6.2.2).

Adding this to the 6.68 billion CHF from above, in total, this amounts to about 6.7 billion CHF in hidden costs of imports, which is dominated by the biodiversity impacts. Importantly, this cost estimate covers GHG emissions, biodiversity and water scarcity, as well as imported mineral fertilizers only, and neglects the health costs from nitrogen use for production of imported products as well as are the poverty-related costs. In particular the latter can be of considerable importance in the hidden cost estimates of the agrifood system of single countries, especially of such in the low income category (FAO, 2023). The estimates derived here thus rather report minimal values for the total hidden costs related to imported food, feed and fertilizer, which in reality likely are higher. However, no such simplified estimation as for the other categories would be readily possible.

Finally, we mention that there is also another study reporting environmental impacts of food and feed imports to Switzerland (EBP 2022), based on very different methods than

[41] The values are derived from the information provided in the reference scenario in figure 6 in this report.

[42] 0.3*3.5 billion CHF + 0.75*7.5 billion CHF +3*0.0012 billion CHF = 6.68 billion CHF.

the assessments done in Furrer et al. (2021).[43] EBP (2022) arrives at considerably higher estimates for the environmental impacts of food system-related imports, amounting to about 2.5 times the domestic impacts, i.e. about 6.25 times the impacts reported here. Here, we adopt a conservative approach and use these lower numbers, indicating, as already pointed out above, that these may rather be a lower-end estimate of the hidden costs of imports.[44]

6.4 Summary of the refined and complemented hidden cost assessments and comparison to other estimates

Here we collect the various refinements and additional estimates to the SOFA 2023 hidden cost assessment discussed above and compare it to some other studies. We emphasize that none of the refinements lead to reduced uncertainties, rather to the opposite, given the additional numbers taken from other studies with different methodological quantification approaches. It is important to emphasise once again that, in our view, the core of TCA is not primarily to present the costs in much detail and with low uncertainty, but to make the hidden costs and their magnitudes visible in order to identify entry points for policy actions, trigger conscious decision making and foster the agrifood system transformation pathways in Switzerland (cf. section 7).

6.4.1 Refined and complemented assessment

Compiling the results of the refinements and complements to the SOFA 2023 hidden cost estimates results in a figure of total hidden costs of the Swiss agrifood system which is more than 40% higher than the original estimate (Table 3). This is mainly driven by explicitly including costs of biodiversity losses[45] which are missing in the SOFA 2023 estimates, and by higher costs of GHG emissions, due to higher values for the social costs of carbon than in SOFA 2023. A number of smaller cost increases from refinement and complements lead to some further increase of the cost estimates, but not dominating as the other two categories mentioned. In addition, one may add the direct and immaterial costs of unhealthy diets, which amount to about two third of the original estimate (17 billion CHF; 15 billion US$ 2020 PPP). These cost categories are more contested as hidden costs and thus reported separately. These costs are however even more contested than the additional health costs and only an unknown share of them may count as hidden. In sum, we suggest to use a refined assessment of total costs of 31.8 billion CHF instead of 21.1 billion CHF, thus adding the biodiversity costs and the refined costs of GHG emissions, etc., but not reporting the more controversial aspects in the hidden cost estimates (additional health costs and cost of subsidies, border protection and other

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[43] EBP (2022) use input-output tables amended with environmental indicators.

[44] Investigation on the discrepancies to EBP (2022) is still ongoing. They likely relate at least partly to the focus on commodities consumed adopted in EBP (2022), i.e. disregarding the impacts related to emissions from exported goods, while Furrer et al. (2021) adopt a production focus also covering the products that are exported.

[45] Maybe partly double counting with the ecosystem/ biodiversity related aspects of N emissions and LUC covered in SOFA 2023, but given the magnitude of these estimates, such double counting will not dominate.

incentive schemes). Nevertheless, we suggest to not neglect those when identifying entry points for action, in particular the costs related to incentive schemes. These new estimates amount to about 4.5% of Swiss GDP in 2020.[46]

For completeness, we again emphasize that the system boundaries behind these estimates are generally national, meaning that these are the costs of the Swiss agrifood system that arise in Switzerland. Thus, impacts on biodiversity, health, etc. refer to the impacts arising within national boundaries. The only exceptions are GHG emissions, where the social costs of carbon cover global damages, as GHG are global pollutants, and nitrogen, where the impacts refer to the quantities leached to waterbodies and ecosystem in Switzerland, while the impacts may arise downstream in other countries (they are however all priced with the marginal costs that apply to impacts in Switzerland). Importantly, the estimates do not include impacts of the production of imported inputs (feed, fertilizer, fuel, etc.) and food. To nevertheless make visible the embedded hidden costs in imported food and feed, we in addition report some estimates for those separately.

Finally, a remark on uncertainties is appropriate. The refinements and complements of the cost estimates undertaken here do not come with a systematic assessment of uncertainties. These are however large and need to be kept in mind – in particular also in the context of their importance in the original SOFA 2023 estimates, where it is advised not to report mean values without uncertainties, and rather to report statements such as which cost level is achieved as a lower estimate with 95% probability. Such statements are not possible on these refinements and this large uncertainty not made explicit needs to be kept in mind.

Table 3: Refined and amended hidden cost estimates of the Swiss agrifood system (values are in billion CHF; to derive 2020 US$ PPP values, they have to be divided by the appropriate PPP conversion factor of 1.105 (World Bank, 2024)). An entry "-" means that this value has not been estimated (for detailed explanation, see the corresponding sections in this chapter 6)

Category	**SOFA 2023 value (billion CHF)**	**Refined/ comple-mented value (billion CHF)**	**Cost difference SOFA 2023 to refine-ment**	**Notes**	**Results from other studies (billion CHF)** (cf. section 6.4.2)		
					Perotti 2020	Dümmler and Roten 2018	Schläpfer 2020
Refinements							
Health – basic estimate	17.1	17.1	0	No change	13.4	-	-

[46] Bruttoinlandprodukt (admin.ch)

Category	**SOFA 2023 value (billion CHF)**	**Refined/ comple-mented value (billion CHF)**	**Cost difference SOFA 2023 to refine-ment**	**Notes**	**Results from other studies (billion CHF)** (cf. section 6.4.2)		
					Perotti 2020	Dümmler and Roten 2018	Schläpfer 2020
Health – additional costs	-	8 9	8 9	Direct treatment costs Immaterial health costs	-	-	-
GHG emissions	0.9	3.1	2.2	Based on a simplistic extrapolation due to higher social costs of carbon values (CHF 430/tCO_2e), not including a consistent modelling (hence used with a conservative correction factor of 50% of the original costs when using the new social costs of carbon values; for details, see section 6.2.2)	1.2	1.5	0.8
Nitrogen emissions	2.9	2.9	0	No change	1.1 (health impacts from air pollution)	0.37 (environmental costs)	2.0
Water use	0.0013	0.0013	0	Negligible – but needs to be monitored closely to early identify potential challenges from water scarcity and related increasing (hidden) costs from water use, e.g. in the context of climate change	-	-	-
Water pollution	-	-	-	Not added separately, partly covered in other categories such as nitrogen emissions or pesticides, see sections 6.2.4 and 6.3.4 .	-	-	-
Poverty	0	0	0	No change; but needs to be monitored closely, it is a morally important aspect and maybe underestimated;	0.5	-	-
Undernourishment / Malnourishment	0	0.57	0.57	Recalculating the values for protein–energy malnutrition and adding the values for iron deficiency.	-	-	-
Land use change	0.22	0.22	0	Potentially 10 times higher, but very uncertain estimates; due to potential double	- (included in the	-	-

Category	SOFA 2023 value (billion CHF)	Refined/ complemented value (billion CHF)	Cost difference SOFA 2023 to refinement	Notes	Results from other studies (billion CHF) (cf. section 6.4.2)		
					Perotti 2020	Dümmler and Roten 2018	Schläpfer 2020
				counting with biodiversity (added below) this is not changed	biodiversity estimate		
Complements							
Phosphorus	-	-	-	Not added (high complexity and likely partly covered in the nitrogen use costs as on the rather aggregate level of detail of the hidden cost estimates, differentiating between nitrogen and phosphorus is difficult for some central impacts such as eutrophication)	-	0.2	-
Soil health	-	0.17	0.17	Relatively small and not covering all aspects of soil fertility and soil health loss. Thus, needs to be monitored closely, as avoiding soil fertility and soil health losses and conserving soils is central for agriculture.	0.004 (soil organic carbon loss)	0.14 (loss of organic soils)	0.007 (erosion)
Biodiversity	-	7.5	7.5	Mid-value of a range from 5 to 10 billion CHF. One of the most central complements to SOFA 2023; maybe partly double counting with the ecosystem/ biodiversity related aspects of N emissions and LUC, but given the magnitude of these estimates, such double counting will not dominate.	10.4	4.9	0.11 (category "habitat deficit", but measures payments for biodiversity friendly land management)
Pesticide use	-	-	-	Not added, but needs to be monitored closely, toxicity from pesticide use should still considerably drop. Impacts on biodiversity are covered under "Biodiversity" above.	0.05 (only health impacts)	0.075	0.27
Antimicrobial resistance	-	0.15	0.15	Not yet important, but may become so in the future: close monitoring is central to be able to take early actions if the	0.27	-	-

Category	SOFA 2023 value (billion CHF)	Refined/ complemented value (billion CHF)	Cost difference SOFA 2023 to refinement	Notes	Results from other studies (billion CHF) (cf. section 6.4.2)		
					Perotti 2020	Dümmler and Roten 2018	Schläpfer 2020
				situation worsens, to avoid potentially large future problems			
Animal welfare	-	0.11	0.11	Relatively low compared to other estimates, but animal welfare improvements are clearly still possible.	0.11	-	0.38
Summed values							
Total SOFA 2023	**21.1**						
Total refinements plus complements		**31.8** (**48.8** when including additional health costs)					
Total difference between refinements/ complements and SOFA 2023			**10.7** (**27.7** when including additional health costs)	10.7 are rather uncontested hidden costs, with biodiversity being most central (7.5 billion); 17 billion are due to additional health costs (i.e. direct and immaterial health costs).			
Imports (reported as a separate category due to different system boundaries than for the other categories)							
Imports		6.7	6.7	Gross estimate covering biodiversity, GHG emissions and water scarcity; high uncertainty and rather a lower limit.	1.3	-	-

6.4.2 Comparison to other studies

Here, we shortly compare the estimates presented above to existing studies on hidden costs of the Swiss agrifood system. The quantitative results from these other studies are also collected in Table 3 above.

First, there is the study Perotti (2020). This is, besides the SOFA 2023 background paper, the most recent and encompassing assessment of hidden costs of the Swiss agrifood system available. We used parts of her assessment and estimates to refine and amend the values provided by SOFA 2023, cf. the corresponding section above. Most central differences of Perotti in comparison to SOFA 2023 are the explicit inclusion of the hidden costs of biodiversity loss as well as the inclusion of economic costs related to subsidies and various support measures. We included the cost estimates for biodiversity loss in our amendments to the SOFA 2023 results. The other economic costs, however, are covered in more detail in another study (cf. the next paragraph on Dümmler and Roten (2018)), and we take them from there. Taken together, Perotti arrives at hidden costs totaling just under CHF 33 billion, wherein health comprises slightly less than half (15 billion) and biodiversity is with 10 billion the next relevant category, with large uncertainty, though. Furthermore, direct economic costs are not considered in our but in her assessment, equaling somewhat more than 4 billion CHF. These are the direct costs reported in Dümmler and Roten (2018), which publication we shortly address just below. Importantly, the health costs of Perotti (2020) do not only cover the costs of unhealthy diets, as in the SOFA 2023 report, but also the costs due to pesticide and particulate matter exposure, food poisoning and antimicrobial resistance. The estimates are in the same order of magnitude, albeit the data used are different, and partly also covering direct costs (i.e. treatment costs of the diseases), which are not covered in SOFA 2023.

Perotti (2020) also provides some estimate for the hidden costs of imports. She determines those by the share of hidden costs in relation to total value generation for the domestic agrifood system and then applies this share to the monetary value of net imports, resulting in 1.4 billion CHF, deemed an underestimation by Perotti. The approach we pursue in our calculations above is more detailed and thus more appropriate, as it differentiates between impact categories and their specific costs.

Second, there is the study by avenir Suisse, Dümmler and Roten (2018), focusing on direct and indirect, predominantly economic costs. They estimate these costs to about 20 billion CHF, whereof about one third are environmental costs (7.9 billion CHF). They do not address health costs related to unhealthy diets. The big part in their estimate are economic costs, covering direct costs such as direct payments and subsidies as well as investments in research, monitoring, etc., at about 4.3 billion CHF (which (Perotti, 2020) directly uses in her estimates), and indirect economic costs. The latter are the costs of higher consumer prices due to border protection (4 billion CHF), foregone income due to lack of free trade agreements (3.1 billion CHF) and the costs of various agricultural privileges such as tax reductions and investment support (1.2 billion CHF), thus summing to about 8.3 billion CHF.

Third, there is the assessment of Schläpfer (2020). He estimates external costs of agriculture from agri-environment avoidance expenditures that can be seen to reflect what society is willing to pay for avoiding negative externalities. This is thus a very different approach than the one followed in SOFA 2023 or Perotti (2020). External costs are derived for emissions of greenhouse gases, ammonia, nitrate and pesticides, soil erosion, habitat deficits, and animal suffering. The total external costs of Swiss agriculture estimated in this way amount to between CHF 3.7 to 5.6 billion.

Besides these studies providing estimates of the hidden costs of the Swiss agrifood system, there are a number of studies conducted in other countries, which may serve as additional source for consistency checks or for inspiration on how to cover certain aspects of such estimates. First, there are the other countries covered in the global assessment of SOFA 2023, as e.g. exemplified in the Swiss background paper Lord (2023b) with comparisons to France, Belgium, Denmark and Ireland, as well as with regional averages for Europe and other world regions. For results on these countries, we quote from Lord (2023b), caption to his figure 3: "All the Western European countries have a broadly similar composition of hidden costs, where productivity costs of unhealthy diets are the largest component. Nitrogen emissions are the largest environmental externality for all countries, with ammonia NH_3 emissions the major component. France and Ireland have proportionally larger agricultural sectors with increased land-use transitions and habitat loss, resulting in more prominent costs from land-use activity."

Then there is a number of specific studies from other countries done within other contexts than SOFA 2023, as e.g. for the US (Rockefeller Foundation, 2021a,b). With two times the direct costs of the agrifood system, this study arrives at somewhat lower relative values for hidden costs in the US than SOFA 2023 for Switzerland (where the hidden costs are with about 3.6% of GDP 3.6 times higher than the direct costs at 1% (Lord, 2023b)). Similar to the Swiss case, this study however also identifies health costs as the biggest part in hidden costs for the US. For this report here, we did however not undertake a systematic search and comparative review of such other country studies.

Furthermore, there is the ongoing Sinergia Project "The True Cost Accounting for Food" at the E4S Center, cf. Barjolle et al. (2023), E4S (2024). No quantitative results are available yet, but it addresses the same topics as we do here and close exchange took place during this project, as representatives of the E4S project were part of the monitoring group.

7. Entry points for food system transformation pathways based on hidden cost estimates

The main interest in hidden cost estimates in the context of this report and the work of SOFA 2023 and 2024 lies in the support that such estimates can provide for the development of transformation pathways for the agrifood system and the related societal and political processes. The focus is thus less on a very detailed and accurate quantification to improve the knowledge base, and more on robust estimates as a basis for argumentation and for the identification of entry points for such transformation pathways. This also means that the focus is not consistency of estimates and a high level of detail, but on identifying the most central cost categories, ensuring that nothing important is neglected and making a rough estimate of their size.

When talking about transformation, the size of the costs is a first general indicator of relevance, however, implementation and potential political, technical, cultural, etc. barriers are also to be considered. It is also important to state that reducing the hidden costs to zero is not the goal. It is important to adopt a pragmatic approach, taking into account both the relevance of a certain cost category and the potential for successful implementation of measures to support agrifood system transformation related to it. This section builds on the refined and amended estimates presented above to identify such entry points for transformation and discusses a number of important aspects for those. Finally, for categories where the overall size of the costs is small, their relevance for certain groups may be overlooked. Iron deficiency is e.g. deemed of minor relevance in Switzerland, but it could be that it is central for certain groups of the population for whose quality of life it is important to take action.

7.1 Entry points from the refined and amended hidden cost estimates

The refined and amended hidden cost estimates provide a relatively simple message: key entry points for action towards food system transformation should focus on (i) unhealthy diets and (ii) biodiversity as the largest cost categories, plus on (iii) GHG and (iv) nitrogen emissions as the two next largest ones. Furthermore, action should be taken on (v) food and feed imports, as those also cause high hidden costs, and (vi) the existing regulatory and payment schemes of agricultural policy should be scrutinized, as a share of those also results in potentially considerably high hidden costs.

We acknowledge again that the financial costs of regulatory schemes etc. are not of the same cost characteristics as the other categories. Their mere amount and partly adverse effects however warrant close analysis on where changes of transformative character may be implemented also in this category. In a context of interdependencies, the motivation to address nitrogen emissions closely correlates with the goals of reducing health costs and biodiversity losses. Furthermore, reducing GHG emissions also closely correlates with reducing nitrogen losses, cf. section 7.3.

Besides these most central cost categories, good monitoring and prospective planning should assure that water scarcity, antimicrobial resistance and soil fertility do not turn into problems with potentially high hidden costs in the future.

Of a somewhat different nature is the topic of decent working conditions, wages and income of agricultural workers and farmers, which has to be seen in a more general context of equity and justice in a society and its economy. Acting on this and achieving acceptable minimal standards for all that are beyond a mere poverty line are of central moral importance for a society, but are rather a general aspect of justice in the labour context than of central relevance as an entry point for food system transformation.

Finally, imports need to be addressed, given the estimate for their aggregate hidden costs lying on a similar level as the domestic biodiversity impacts. They also have a different standing than domestic production, and are not part of the estimates in SOFA 2023, given the system boundaries chosen there. The relevance of food imports to Switzerland, and the clear signal from the monitoring group to account for those in some way in the refined hidden cost estimates, justifies highlighting them as a key issue.

7.2 Attribution of costs

Attribution addresses the question of which group of decision makers is in a position to decide on which aspects of the various hidden cost categories. Attribution is about understanding the cause-effect chains as well as relevant interdependencies in order to identify cost producers. However, understanding the system dynamics and attributing the costs can be complex. And when it comes to defining the cost producer of the costs, one has to consider the entire value chain. It is crucial to emphasize that the goal thereby is not to blame cost producers for the costs they produce but rather to understand underlying mechanisms and use this information to identify promising entry points for most effective intervention towards reducing these costs and transforming agrifood systems.

Identifying entry points via attribution requires to develop some gross understanding of the core system dynamics in the context addressed in order to avoid misidentification of the central leverage points. If done correctly, such attribution can help to identify "low hanging fruits" for effective action. Without some attribution and more refined differentiation of cost producers such effective and targeted action is not possible. Such attribution and differentiation is also central for entry points for action on hidden costs of imports and food waste (cf. below), these categories being an aggregation of very heterogeneous products, whereof some are much more central as cost drivers than others (e.g. regarding biodiversity or water use impacts of imports). To work on those two categories imports and waste, the first central step is to identify the single commodities and commodity groups causing the largest hidden costs.

Importantly, the cost producer is not necessarily the decision maker to be targeted directly. An example are agricultural GHG emissions and dietary health costs. The attribution of costs raises the question of the extent to which consumers are primarily responsible for their dietary choices or the extent to which consumers are restricted or influenced in their consumption decisions (food environment, culture/tradition, advertising, prices – also influenced by subsidies on the production side, etc.). Given the relevance of the food environment for consumer choices, retailers can be among the key ultimate drivers behind the hidden cost producing decisions of consumers as cost producers regarding health effects and part of the GHG emissions. For agricultural GHG emissions, key sources are methane from ruminants, methane and nitrous oxide from livestock manure management, and nitrous oxide from fertilized soils. The quantities of these different emissions are known in detail, e.g. from the national GHG inventory (FOEN, 2024c). These emissions are associated with various cost-causing aspects that have to be taken into account in the attribution process: in addition to managerial and technical improvements to reduce emissions, the link between agricultural production and consumer demand has to be considered. By choosing to consume meat and dairy products, consumers contribute to the generation of GHG emissions.

Any analysis of attribution of costs to cost producers is closely linked to the analysis of interdependencies (cf. section 7.3). As also illustrated with the examples above, a thorough analysis should focus on the drivers of these costs in relation with the relevant decision-makers. It should be avoided to look at these decision-makers merely as cost producers, without acknowledging their situation in the complex set of interdependencies, incentive schemes, drivers and pressures imposed by other market players and various climatic, agronomic, institutional and policy-related constraints on actions.

7.3 Interdependencies

As already mentioned, the goal of the hidden cost estimates is less on giving detailed information on the cost levels than on giving inputs to food system transformation processes. Thus, any quantification needs to be scrutinized regarding effort required and relevance achieved and whether other aspects may be more important for the transformational goal.

One such aspect are interdependencies between different cost categories such as between nitrogen emissions and greenhouse gas emissions. Such interdependencies allow to achieve improvements in several cost categories by acting only on one of them. Identifying such interdependencies is thus important for efficient design of measures to support food system transformations based on hidden cost estimates and reduction.

Focusing on these interdependencies when designing cost-reducing measures means that systemic aspects of the agrifood system are taken up consistently. Reductionist approaches with too narrow a focus that are therefore unlikely to be efficient, are thus avoided. There is much research available on such interdependencies and a literature review could provide some synthesis of the evidence on interdependencies between different categories of hidden costs, or between reducing certain hidden costs and achieving other desired outcomes. This is however beyond the scope of this case study report. The relevant core linkages can be named without these additional efforts, though by referring to some basic relationships and core publications implicitly capturing these linkages in detail. This is shortly presented in the following, naming some of the key interdependencies, acknowledging that there are many more.

First, there is the relation between an overall too high food intake, high consumption of red meat, processed meat and sugar and the cropland, plant protection chemicals and nitrogen fertiliser used for this production. Second, there is the connection between high cropland use for livestock production, high feed imports, and low nitrogen use efficiency, i.e. high nitrogen losses, in livestock value chains (FOAG, 2023; De Luca & Muller, 2023). Third, there is the national GHG inventory report, which highlights the relevance of nitrogen use and livestock's nitrogen excretion for GHG emissions (FOEN, 2024c). Fourth, there are the relations between direct payments, border protection and other support and production patterns that contradict dietary health goals. Fifth, there are the connections between high nitrogen throughput and losses, high pesticide use, subsidy schemes and biodiversity losses (Gubler et al., 2020b).[47]

[47] The study from Meier et al. (2022) may be used for a detailed assessment of drivers of farmland biodiversity in Switzerland.

7.4 Food loss and waste

Food waste is no focus topic in the SOFA 2023 report. Most directly, emissions and impacts such as greenhouse gases and water consumption generated during disposal of food waste are taken into account. The most important characteristic of food waste in high income countries, though, is its quality as food having been produced in vain. Thus, the production of the food wasted could ideally have been avoided – just as the related impacts and direct and hidden costs. Clearly, part of the food waste is unavoidable, but a significant share is avoidable.[48] Related shares are around 30 percent of food supply in Switzerland, depending on food categories, thus resulting in about 2.8 million tons of avoidable food waste every year (Beretta & Hellweg, 2019).

Avoiding this food waste has the potential to also reduce the hidden costs and other inefficiencies of the agrifood system[49]. In this, food waste and its reduction are not specific to hidden costs, and related quantification would not add to the hidden cost assessments, but the big leverage related to it makes food waste reduction a central entry point for improvements also for hidden cost reduction. This is thus clearly relevant in the Swiss context, where the disposal problem of food waste is negligible, while the aspect of avoidable useless production is not.

7.5 Synthesis

In sum, priority entry points for action regarding hidden cost reduction and food systems transformation lie in reducing unhealthy dietary patterns, supporting biodiversity protection and scrutinizing the existing subsidies and other incentives. Furthermore, action on reducing nitrogen use and greenhouse gas emissions is needed, as well as on reduction of food waste.

In as much as interdependencies are concerned, those can help to build on synergies between nitrogen use and GHG emissions reduction and biodiversity protection. Furthermore, the reduction in production coming from food waste reduction and also from shifts in diets also support this. For both these aspects, impacts however may manifest domestically or abroad, depending on whether food waste reduction results in less domestic production or less imports and of what kind. Similarly for changes in

[48] Unavoidable food waste refers to parts that cannot be eaten or cannot be avoided due to technical conditions (e.g. losses due to cleaning of production plants). A share of non-avoidable food waste refers to commodities that are not commonly eaten in a specific society (such as chicken feet in Switzerland). This clearly opens room for discussion and may look different in the future, but for now, commodities usually deemed not eatable by a majority of the population are also deemed unavoidable in the study of Beretta and Hellweg (2019). Hence, the avoidable food waste covers all the rest.

[49] Environmental impacts arise even in an ideal market context, where all external costs are internalised. In case some of these impacts are related to the production of food commodities that are then wasted, reducing this production by avoiding waste would correspondingly reduce these environmental impacts and related economic damages (albeit the are fully internalised).

dietary patterns, this may well affect the domestic or foreign production. Some trade-offs may also arise there, as e.g. production of vegetables that should take increasing shares in healthy diets is highly intensive and thus particular focus has to be put on its sustainability to avoid increase in nitrogen losses and impacts on biodiversity.

Finally, attribution of costs, or, framing it differently, of the identification of who can take action regarding the decisions that directly cause hidden costs and who can take action regarding drivers influencing those decisions is central to identify most promising entry points for change. This necessitates knowledge of the decision makers and structures along the whole value chain. For example, it is the farmer who applies pesticides, but drivers from the downstream value chain influence some of the respective decisions (such as various quality requirements from processors, retailers and consumers). The sovereignty to take decisions for change lies thus not necessarily fully with the cost producers. Well-designed consistent changes along the whole value chain are required to allow for efficient solutions.

8. Conclusions

In this chapter, we draw a number of conclusions, first referring to the refined and amended quantitative cost estimates and then addressing a number of broader topics related to food system transformation.

8.1 Quantitative results

1) SOFA 2023 provides a good basis for country specific analysis of the hidden costs covered. However, important aspects need to be added, resulting for Switzerland in a total of 31.8 instead of 21.1 billion CHF annually.

The assessment of the SOFA 2023 report, the analyzed potential refinements and complements of important topics for Switzerland and other existing studies and data show that the SOFA 2023 estimates provide a good basis for country specific analysis. The topics covered in SOFA 2023 are generally captured quite well. A central difference arises, however, on the level of the social costs of carbon for estimating the hidden costs of GHG emissions. There, Switzerland calculates with higher values than SOFA 2023 resulting in total costs from GHG emission that are three times as high as the SOFA 2023 estimates. Furthermore, some central topics are missing in SOFA 2023, due to lack of global datasets. In the case of Switzerland, these are in particular the costs of biodiversity losses that result in an additional cost of 7.5 billion CHF. In total, the refined hidden cost estimate thus amounts to about 31.8 billion CHF instead of 21.1 billion CHF. Further complements cover direct and immaterial costs of unhealthy diets, which are however more controversially discussed regarding their characteristics as being hidden costs. They amount to an additional 17 billion CHF. It is important to name them, but we suggest to not add them to the central refined hidden cost estimate. This also applies to a third category of costs, namely those arising from subsidies, border protection and other incentives. Also those costs should be made explicit but may not be added to the central hidden cost estimate, as they are even more controversial regarding their quality as being hidden costs than the additional health costs. Finally, hidden costs of imports have to be mentioned, amounting to about 6.7 billion CHF, i.e. adding again about 20% of the refined hidden costs estimates presented here. Addressing the hidden costs of imports is not consistent with the system boundaries of SOFA 2023, but it is not controversial regarding their quality as truly hidden costs and their relevance in the Swiss agrifood system.

Importantly, all these numbers are not accompanied by explicit uncertainty estimates, as strongly suggested in SOFA 2023, and in consequence, it is important to acknowledge that the uncertainty of these numbers is large, albeit not being quantified systematically.

2) It is central to not only focus on reducing these biggest costs, but also to make sure that cost categories that are currently small do not develop into big costs in the future. Prime examples here are costs related to antimicrobial resistances and water scarcity, summing to only 0.15 billion CHF currently.

Avoiding that these currently low hidden costs arise at high levels in the future, would keep societal costs much lower than acting on adverse impacts in those areas later to reduce increased hidden costs. Besides antimicrobial resistance and water scarcity already named above, soil fertility loss is an important topic in this category. Currently, none of these cause significant hidden costs in Switzerland, but there is a risk that this may change in the future, e.g. due to climate change impacts or due to accelerated dynamics of resistances development. Hence, it is of paramount importance to monitor these areas closely to be able to act early in order to avoid high costs in the future.

3) True cost accounting can help giving due weight to aspects that are often neglected – but also bears the danger that aspects that are difficult to quantify are counted with zero costs.

There are other costs that are also currently not that relevant but of somewhat different nature. These are the hidden costs of poverty and animal welfare, which are very much dependent on value judgements on inequality and justice as well as on the relation of humans to animals. TCA offers a somewhat objective approach to make potential costs commensurable with others, but in these categories, this is particularly contested. Importantly, naming these categories albeit they do not show high costs helps to draw attention to them and to emphasize that explicit and conscious decisions on these aspects are needed – which working conditions and salaries do we, as a society, accept in agriculture and food sectors, how do we treat our livestock?

This is also a potential danger of TCA approaches: if a certain cost category cannot be estimated it tends to be left out – which is however equivalent to assign it a zero value. Thus, there is particular caution warranted to avoid that cost categories not covered are automatically and implicitly assumed to be low or zero.

8.2 How to use TCA estimates and entry points for transformation

4) True cost accounting has big potential as an information and communication tool.

TCA offers a consistent economic approach to indicate where decisions are taken in a biased way because they do not account for all consequences, and where such bias may be most relevant, offering key entry points for food system transformation. Clearly, not all relevant aspects are captured in this, but by its firm basis in economic thinking, it has the potential to be accepted by the major stakeholders. This indication of where decisions are not taken with full accounting for all economic consequences is a core role of hidden cost estimates. In this, the large share of health costs in the estimates for Switzerland (and many other countries in SOFA 2023) should thus be used as an alarm signal for where the society faces an important problem, and less as a signal that all other costs are less important in comparison to those costs and thus may not warrant priority action. All the more, the inclusion of biodiversity and also imports is central, as these amount to levels of a similar magnitude as the health costs, albeit also with large uncertainties. This country case study for Switzerland can also serve as an illustration for other countries on how to make best use of the SOFA 2023 estimates, and how to identify areas where additional estimates are needed.

Importantly, some flexibility both regarding concepts and indicators is required when implementing TCA approaches on country level in a context of supporting agrifood system transformation pathways. Flexibility in the definition of the concepts is possible, because to serve the purpose, the concepts need to quite generally capture costs and adverse impacts that are neglected in decision making processes – this is then captured by "hidden costs". Furthermore, it makes sense to also offer another, narrower concept relating to such costs in explicit market contexts, then being captured by the "external costs". Flexibility regarding indicators and cost data is acceptable, because the purpose of those is to provide an indication of the order of magnitude of hidden costs related to certain impact categories such as greenhouse gas emissions or reduced health. Given the complexity of the task to estimate such hidden costs, the many assumptions made and the uncertainties involved, anyway only gross quantification is possible.

5) Reducing food waste is a central topic, as not producing something instead of producing and then wasting it results in avoiding the related hidden costs.

Given the size of food waste in Switzerland, this is one central entry point for action. Clearly, the aim cannot be on reducing food waste to zero, but already a significant reduction would contribute much to more sustainable agrifood systems.

6) Accounting for interdependencies between different topics is important to build on potential synergies between them and to avoid trade-offs, where possible.

Food waste reduction, for example, does not act on reducing dietary health costs. Other entry points are required for this. Besides targeted action on consumer behavior and food environments, addressing and building on interdependencies is central for this, as there are strong relations between how and what we produce and how and what we consume, or between different aspects of current production systems and their impacts, such as high nitrogen and pesticide use and certain subsidy schemes.

7) Identifying the cost producers and, in particular, the drivers influencing the behaviour of cost producers is central for the development of effective policy instruments.

Key for identifying entry points for action are also the attribution of cost production, to move from food system levels to those parts where costs arise. Identification of such attribution is beyond the scope of this report, but a first indication regarding GHG emissions and nitrogen can be gained from the GHG inventory and nitrogen balance calculations, for example. This illustrates the importance of the livestock sector for nitrogen use, importantly also highlighting the role of high livestock numbers fed on imported feed and the cropping patterns with large cropland areas under feed cereal and forage maize production. Such differentiation and attribution is clearly also central when addressing the hidden costs of imports and food waste.

Importantly, attribution of costs needs to be done in a context of mutual support towards the required changes and improvements rather than in a context of mere blaming without suggesting options for change. Furthermore, cost producers take their decisions in a rich institutional and societal context, and it is central to identify the related drivers for the cost producers' decisions to identify most promising entry points for transformation.

Regarding dietary health impacts, for example, it is clearly individual consumers that decide on what they eat – but this is never done in a void space and food environments play a central role. Thus, addressing the responsibility of the whole food sector, advertisement and retailers is central here, as well as the role of education, dietary counselling and gastronomy. It remains yet to be investigated how important these aspects are in individual consumption decisions in Switzerland, but much research is available on this, also from other countries, which should be synthesized.

As is often the case, the implementation of theoretical suggestions in practice is a complex process. It is essential to build upon existing knowledge regarding the optimal design of instruments that facilitate transformation pathways and the concrete implementation of hidden cost reductions. Furthermore, it is important to identify potential design flaws that should be avoided.

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Appendix I – TCA Process Documentation

This appendix shortly describes the process undergone in the course of writing the Swiss Case Study paper to the SOFA 2023 report, in particular focusing on challenges and outcomes.

Process

The process ran from October 2023 till May 2024 and was organised around five types of expert groups.

- First, there was the core writing group consisting of experts at the service provider, the Research Institute of Organic Agriculture FiBL.
- Second, there were the experts from the commissioning client's side, representatives of the FAO SOFA team.
- Third, there were representatives from the Federal Office of Agriculture FOAG Switzerland, as the contact point for SOFA in Switzerland and for the core writing group.
- Fourth, there was a monitoring group of experts from various governmental, academic and other institutions in Switzerland, with the role of critically reviewing draft versions of the report and providing inputs at specific monitoring group meetings.
- Fifth, there was Steven Lord, as the author of the model behind the SOFA 2023 calculations, available for methodological questions and refined calculations for Switzerland.

The process involved a kick-off meeting and three monitoring group meetings, where also the other expert groups named above took part, and various additional meetings on specific questions as required, bilaterally or in small groups. Furthermore, a draft outline, and at a later stage draft reports were circulated with all experts involved, collecting specific comments that were then subsequently addressed. These comments explicitly also involved inputs on further experts to contact for specific topics, links to additional studies and data sources of interest, as well as on related ongoing, planned or completed projects.

This process organisation allowed to collect inputs from a very broad range of experts. These inputs allowed to clarify and refine the structure and narrative of the case study, to sharpen the arguments used, to make expectations of the various experts and institutions involved explicit and to identify and fill or correct gaps and unclear formulations where needed. Furthermore, the broad range of experts assured linkage to any similar process ongoing in the institutions involved, thus allowing to identify synergies and complementarities as well as to avoid duplication.

The process was characterised by great openness and respect among all people and institutions involved and was perceived by the core writing team as a very fruitful common learning experience.

Challenges

The process itself went smooth (besides some delay towards the end, on the service providers' side), but topically, it clearly was not without challenges. Most important were the following aspects:

- Definition and representation of the various costs
    - There were repeated discussions on how exactly to define the various cost categories, which costs should be termed external or hidden and which not, and in particular also which type of costs legitimate governmental intervention; this also linked to how external costs and true cost accounting or other terms are used in Switzerland in various contexts and governmental institutions.
    - There were discussions on how to separate and present the various cost categories, e.g. health, social and environmental, and whether and how to summarise them or not in the presentation.
    - Key aspects thereby are also responsibilities for action, e.g. regarding dietary health costs – to which extent are the individual consumers or the agrifood system actors responsible for those?
    - It was also somewhat controversial which additional costs should be added and which refinements should be done to the existing costs and whether it is better to aim at improved coverage of the existing cost categories or broader coverage of additional ones.
- Different expectations regarding the contents, goals and impacts of the report
    - There were partly differing opinions among the various experts and institutions on what the report should cover or aim at, and where to put a focus on.

      This was e.g. reflected in different views on how concrete suggestions regarding policy action may be formulated, how strongly a consumer, producer or rather general value chain focus should be adopted and how explicitly specific sectors should be targeted as cost producers and thus addressees of implementation.

      To clarify this very concretely right at the beginning would clearly be helpful for future case studies in other countries.
- Using and perception of the results in the public and policy processes
    - Repeatedly, there were some reservations voiced on how the numbers may be used in the public debates and that it is central to stay in the lead of this process, governing how the numbers are taken up in debates and put into context to avoid misguided use.
    - In this context, specific sensitive issues were named, in particular regarding pointing out specific cost producers, which can easily result in

blaming those for being responsible for the hidden costs; such blaming should be avoided and the (hidden) benefits of the agrifood system should also be given due visibility. This then however bears the danger that summing these numbers may result in making the hidden costs less visible, which would be a danger for the success of the whole exercise as an input to food system transformation pathways. The level of concrete ness of suggestions for action and whom to target them to thus remained controversial.

- How to deal with missing topics?
    - Different opinions arose on how to deal topics that are deemed relevant but due to missing data cannot be included to the same quantitative extent as those topics already covered. Not including such topics would be methodologically consistent but would implicitly assign a value of zero, which is definitely not correct.
    - Including such topics qualitatively would not be consistent with the existing methodology and any communication of such combined quantitative and qualitative assessments needs to be done very cautiously to transport unbiased messages.

Outcomes

The process resulted in a number of important outcomes:

- Compilation on existing hidden cost assessments in Switzerland, on where data for additional assessments are available, and which experts to address for details for any topic of interest
- Compilation of important gaps in hidden costs assessments and on which data is missing for closing them.
- A transparent process where all relevant experts could contribute and setting the basis for an encompassing and widely accepted assessment. This does not mean that all experts will agree with the decisions taken for certain aspects in the final report (cf. the description of challenges above), as some suggestions are excluding each other. But due to the process, there are good chances that mutual understanding for any decision taken is present.
- A good basis for finalising the report in such a way as to make it most helpful for the Federal Office of Agriculture FOAG; regarding decisions on controversial matters we generally adopt the view voiced by FOAG as the first user of this report in the policy processes in Switzerland.

Appendix II – Ongoing projects, data, contacts

This appendix lists some few ongoing projects, data sources and further contacts of potential interest for work on TCA in Switzerland, without any claim for completeness (see also the literature list and the people listed in the acknowledgment).

Projects

- True Cost of Food - Main Page – E4S
  - Contact: Dominique Barjolle (dominique.barjolle@unil.ch)
- Berechnung der Kosten der übertragbaren und nichtübertragbaren Krankheiten und der Kosten der Risikofaktoren Inaktivität und Übergewicht in der Schweiz | ZHAW Zürcher Hochschule für Angewandte Wissenschaften
  - Contact: Simon Wieser (wiso@zhaw.ch)

Data / contacts

Environment

- Zentrale Auswertung von Agrarumweltindikatoren (ZA-AUI) (admin.ch) (till 2023)
- Monitoring des Agrarumweltsystems Schweiz (MAUS) (admin.ch) (2023 onwards)
  - Contact: Anina Gilgen (anina.gilgen@agroscope.admin.ch)

Health

- HealthEffects (swisstph.ch)
- Andrea Poffet (andrea.poffet@bag.admin.ch)

Water

- Nationale Grundwasserbeobachtung NAQUA (admin.ch)
- Nationale Beobachtung Oberflächengewässerqualität (NAWA) (admin.ch)
  - Contact: Andreas Hauser BAFU (andreas.hauser@bafu.admin.ch)

Nitrogen

- Stoffflussmodell MODIFFUS (admin.ch)
- Nitrat im Grundwasser (admin.ch)
- https://www.agrammon.ch/

Antimicrobial resistance

- StAR – Strategie Antibiotikaresistenzen (admin.ch)
- VizHub - MICROBE (healthdata.org)
- ARCH-Vet 2022 - BLV - admin.ch

- Jahresbericht IS ABV 2022 (PDF, 3 MB, 07.12.2023)
- Home - ANRESIS
- Switzerland.pdf (healthdata.org)
- Home (nfp72.ch)
    - Contact: Dr. Barbara Flückiger Schwarzenbach, SNSF (nfp72@snf.ch)
- ZOBA – Center for Zoonoses, Animal Bacterial Diseases and Antimicrobial (unibe.ch)
    - Contact: Dr. Gudrun Overesch (gudrun.overesch@unibe.ch)

Soil

- Nationale Bodenbeobachtung (NABO) (admin.ch)
- NFP (nfp68.ch)

Biodiversity

- Monitoringprogramm „Arten und Lebensräume Landwirtschaft" - ALL-EMA (admin.ch)
    - Contact: Eva Knop (eva.knop@agroscope.admin.ch)

Plant protection means/Pesticides

- Risikoindikatoren Pflanzenschutzmittel (admin.ch)
- Human Biomonitoring (HBM) (admin.ch)
    - Contact: Olivier Sandivo SECO (olivier.sanvido@seco.admin.ch)

Poverty

- Einkommen in der schweizerischen Landwirtschaft (admin.ch)
- Agrarbericht 2023 - Betriebe
- Esther Grossenbacher FOAG (esther.grossenbacher@blw.admin.ch)
- Dierk Schmid Agroscope (dierk.schmid@agroscope.admin.ch)