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Global dairy sector: past development and outlook

Insights from the International Farm Comparison Network

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Summary

The global dairy sector has undergone substantial development over the last two decades and is expected to experience a fundamental change in the next decades. The goal of the present report is to provide a comprehensive overview of the global dairy sector developments that have occurred in the last two decades, relying on the unique database of the International Farm Comparison Network (IFCN). Our focus is on global milk production, demand, dairy farm structure, world oil, milk, and feed prices, and dairy trade. We further present the IFCN global long-term outlook for 2030, 2040, and 2050. By providing detailed insights into past and possible future developments of the global dairy market, this report aims to guide stakeholders in the dairy sector in their decision-making process.

Our report is based on the standardised IFCN database, which covers 125 countries representing 99% of the world's milk production. National data standards may vary widely among countries, making direct comparisons between countries difficult. To ensure cross-country comparability, the IFCN Dairy Research Centre, together with research partners from across the world, has developed standardisation methods that it uses to harmonise national dairy statistics and create a standardised database. Besides standardisation methods, the IFCN Dairy Research Centre has developed specific indicators (such as the IFCN Combined World Milk Price Indicator and IFCN World Feed Price Indicator) to monitor the economic situation both at farm and global sector level.

In the last two decades, global milk production has experienced sustained growth despite the global challenges that have occurred in this period (e.g. the 2007–2008 financial crisis and subsequent global recession or the COVID-19 pandemic in 2020–2022, high inflation in 2021–2023). In the period 2000–2023, the growth rate of global dairy production amounted to 77%, that is, 2.5% per year. This growth resulted from a steadily increasing demand driven by two main factors: rising per capita consumption (+36%) and a growing world population (+31%). The increase in demand is especially observed in countries that are not self-sufficient in milk, such as those in Asia, Africa, and Latin America, where economic development has boosted the consumption of dairy products. In response to this sustained demand growth, coupled with a sharp increase in oil and feed prices from 2007 onwards, the IFCN Combined World Milk Price Indicator registered not only a strong increase but also showed a higher volatility compared to the period before 2007. Whereas it ranged between 10.7 and 24.1 USD/100 kg solid-corrected milk (SCM) in the period 1981–2006, it fluctuated between 26.1 and 53.4 USD/100 kg SCM in the period 2007–2023. The link between the dairy market and the oil market has strengthened. Dairy farming worldwide continues to undergo a major transformation. The long-term structural change towards fewer but larger farms is driven by technological advancements, market forces, and sustainability requirements. In 2023, 0.2% of all dairy farms produced 45% of the total milk. Dairy farm consolidation has progressed in most countries and is expected to continue, shaping the future of the dairy sector worldwide.

In terms of outlook, the IFCN expects the global demand for dairy products to increase faster than the supply in the next three decades. The future unsatisfied demand is estimated to be 11 million tons of milk by 2030, with further increase expected by 2050. There are two key drivers behind the expected future development of the dairy market. First, demand will increase due to strong economic growth and population increases in major dairy-importing countries. Second, global supply will be constrained by environmental regulations, climatic conditions or limited land availability in major dairy exporters, such as New Zealand, the EU, and the United States. Other factors that are expected to play a substantial role in the future development of the dairy market are the difficulties in attracting labour to dairy farms and the challenges of recruiting skilled individuals for increasingly digitalised farm operations. An imbalance in dairy trade is expected to increase prices and could therefore lead to a substantial improvement in dairy farming profitability.

Zusammenfassung

Die globale Milchbranche hat sich in den letzten 20 Jahren stark gewandelt und wird in den nächsten Jahrzehnten wahrscheinlich weitere tiefgreifende Veränderungen erfahren. Ziel des vorliegenden Berichts ist es, gestützt auf die einzigartige Datenbank des International Farm Comparison Network (IFCN), einen breiten Überblick über die weltweiten Entwicklungen in der Milchbranche in den letzten 20 Jahren zu vermitteln. Der Schwerpunkt liegt dabei auf den Themen globale Milchproduktion, Nachfrage, Struktur der Milchwirtschaftsbetriebe, Weltmarktpreise für Öl, Milch und Futtermittel sowie gehandelte Milchprodukte. Zudem werden die globalen Langfristperspektiven des IFCN für 2030, 2040 und 2050 vorgestellt. Der vorliegende Bericht soll den Akteuren der Milchbranche genaue Einblicke in die bisherige und mögliche zukünftige Entwicklung des globalen Milchmarkts bieten und ihnen so als Entscheidungshilfe dienen.

Der Bericht beruht auf der standardisierten IFCN-Datenbank, in der 125 Länder, auf die 99 Prozent der weltweiten Milchproduktion entfallen, erfasst sind. Die je nach Land stark variierenden nationalen Datenstandards erschweren direkte Vergleiche zwischen den Ländern. Um die internationale Vergleichbarkeit zu gewährleisten, hat das IFCN-Zentrum für Milchwirtschaft zusammen mit seinen Forschungspartnern weltweit Standardisierungsmethoden entwickelt. Diese werden zur Harmonisierung der nationalen Milchstatistiken und zur Schaffung einer standardisierten Datenbank genutzt. Daneben hat das IFCN-Forschungszentrum für Milchwirtschaft zwecks Monitorings der wirtschaftlichen Situation der Milchbetriebe und der globalen Milchbranche spezifische Indikatoren entwickelt (kombinierter globaler Milchpreisindikator und globaler Futtermittelpreisindikator).

Die weltweite Milchproduktion hat in den letzten 20 Jahren kontinuierlich zugenommen und dies trotz der globalen Probleme, die sich in dieser Zeit gestellt haben (z. B. Finanzkrise 2007–2008 und darauffolgende weltweite Rezession, Covid-19-Krise 2020–2022, hohe Inflationsraten 2021–2023). Im Zeitraum 2000–2023 stieg die globale Milcherzeugung um 77 Prozent an, d. h. um 2,5 Prozent pro Jahr. Das Wachstum erklärt sich aus der stetig steigenden Nachfrage, die zwei Hauptgründe hat: der zunehmende Pro-Kopf-Konsum (+36 %) und die wachsende Weltbevölkerung (+31 %). Vor allem in Ländern, die mit Milch nicht selbstversorgend sind, ist die Nachfrage angestiegen (z. B. in Asien, Afrika und Lateinamerika). So hat die dortige wirtschaftliche Entwicklung den Konsum von Milchprodukten angekurbelt. Als Reaktion auf die stark wachsende Nachfrage und den drastischen Preisanstieg bei Öl- und Futtermitteln ab 2007 ist der kombinierte globale Milchpreisindikator des IFCN deutlich angestiegen und wesentlich volatiler geworden. Von 1981–2006 lag dieser Indikator zwischen 10,7 und 24,1 USD/100 kg trockenmassekorrigierter Milch (SCM), von 2007–2023 variierte er zwischen 26,1 und 53,4 USD/100 kg SCM. Der Zusammenhang zwischen Milchmarkt und Ölmarkt hat sich verstärkt. Der globale Milchsektor befindet sich weiterhin in einem tiefgreifenden Wandel. Technologische Fortschritte, Marktkräfte und Nachhaltigkeitsauflagen treiben den langfristigen Strukturwandel hin zu weniger, aber grösseren Betrieben weiter voran. Im Jahr 2023 wurden 45 Prozent der gesamten Milchmenge von nur 0,2 Prozent aller Milchwirtschaftsbetriebe produziert. Die in den meisten Ländern beobachtete Konsolidierung der Milchwirtschaft dürfte sich weiter fortsetzen und die Zukunft der Milchbranche weltweit prägen.

Laut den Prognosen des IFCN wird die globale Nachfrage nach Milchprodukten in den nächsten 30 Jahren schneller wachsen als das Angebot. Der Nachfrageüberhang wird bis 2030 auf 11 Millionen Tonnen Milch geschätzt und dürfte bis 2050 weiter zunehmen. Die erwartete Entwicklung des Milchmarkts wird durch zwei Treiber bestimmt: Erstens wird die Nachfrage wegen des dynamischen Wirtschafts- und Bevölkerungswachstums in den grössten milchimportierenden Ländern steigen. Zweitens wird das globale Angebot durch Umweltvorschriften, klimatische Bedingungen oder limitierte Flächen bei wichtigen Milchexporteuren wie Neuseeland, der EU und den Vereinigten Staaten eingeschränkt bleiben. Auch der Arbeitskräftemangel in der Milchwirtschaft bzw. das Problem, Fachkräfte für die zunehmend digitalisierten landwirtschaftlichen Betriebe zu gewinnen, werden die Zukunft des Milchmarkts wesentlich beeinflussen. Dieses Ungleichgewicht im Handel mit Milchprodukten dürfte zu einem Anstieg der Preise beitragen und könnte folglich zu einer höheren Rentabilität in der Milchviehhaltung führen.

Résumé

Le secteur laitier mondial a connu un développement considérable au cours des deux dernières décennies et devrait connaître un changement majeur au cours des décennies à venir. Le présent rapport a pour but de présenter l'évolution du secteur laitier mondial au cours des vingt dernières années, en s'appuyant sur la base de données unique du Réseau international de comparaison des exploitations agricoles (IFCN). L'accent est mis sur la production laitière mondiale, la demande, la structure des exploitations laitières, les prix mondiaux du pétrole, du lait et des aliments pour animaux et le commerce des produits laitiers. Le rapport expose également les perspectives mondiales à long terme de l'IFCN pour 2030, 2040 et 2050. En fournissant des informations détaillées sur les développements passés et futurs du marché mondial des produits laitiers, ce rapport vise à guider les acteurs du secteur laitier dans leur prise de décisions.

Notre travail repose sur la base de données standardisée de l'IFCN, qui couvre 125 pays représentant 99 % de la production laitière mondiale. Les normes nationales de données peuvent varier considérablement d'un pays à l'autre, rendant difficiles les comparaisons directes entre les pays. Pour pouvoir comparer les pays entre eux, le Centre de recherche laitière de l'IFCN, en collaboration avec des partenaires de recherche du monde entier, a développé des méthodes de standardisation qu'il utilise pour harmoniser les statistiques laitières nationales et créer une base de données standardisée. Outre les méthodes de standardisation, le Centre de recherche laitière de l'IFCN a développé des indicateurs spécifiques (tels que l'indicateur combiné IFCN du prix mondial du lait et l'indicateur IFCN du prix mondial des aliments pour animaux) afin de suivre la situation économique des exploitations laitières et du secteur laitier mondial.

Au cours des deux dernières décennies, la production laitière mondiale a connu une croissance soutenue malgré les défis rencontrés dans le monde au cours de cette période (par exemple, la crise financière de 2007-2008 et la récession mondiale qui s'en est suivie ou la pandémie de COVID-19 en 2020-2022, l'inflation élevée en 2021-2023). Au cours de la période 2000-2023, le taux de croissance de la production laitière mondiale était de 77 %, soit 2,5 % par an. Cette croissance résulte d'une augmentation constante de la demande sous l'effet de deux facteurs principaux: l'augmentation de la consommation par habitant (+36 %) et la croissance démographique mondiale (+31 %). L'augmentation de la demande s'observe surtout dans les pays qui ne sont pas autosuffisants en lait, comme ceux d'Asie, d'Afrique et d'Amérique latine, où le développement économique a stimulé la consommation de produits laitiers. En réponse à cette croissance soutenue de la demande, associée à une forte augmentation des prix du pétrole et des aliments pour animaux à partir de 2007, l'indicateur combiné du prix mondial du lait de l'IFCN a non seulement enregistré une forte hausse, mais a également affiché une plus grande volatilité par rapport à la période précédant 2007. Alors que le prix variait entre 10,7 et 24,1 USD/100 kg de lait corrigé en matière grasse (SCM) au cours de la période 1981-2006, il a fluctué entre 26,1 et 53,4 USD/100 kg SCM au cours de la période 2007-2023. Le lien entre le marché laitier et le marché pétrolier s'est renforcé. L'élevage laitier dans le monde continue de subir une transformation majeure. L'évolution structurelle à long terme qui se traduit par une réduction du nombre des exploitations au profit d'exploitations plus grandes est induite par les progrès technologiques, les forces du marché et les exigences en matière de durabilité. En 2023, 0,2 % des exploitations laitières ont produit 45 % du lait total. La consolidation des exploitations laitières a progressé dans la plupart des pays et devrait se poursuivre, déterminant l'avenir du secteur laitier dans le monde entier.

En termes de perspectives, l'IFCN s'attend à ce que la demande mondiale de produits laitiers augmente plus rapidement que l'offre au cours des trois prochaines décennies. On estime à 11 millions de tonnes de lait le volume de la demande qui ne sera pas satisfaite d'ici à 2030, et une nouvelle augmentation est attendue d'ici à 2050. L'évolution prévue du marché des produits laitiers repose sur deux facteurs clés. Premièrement, la demande augmentera en raison de la forte croissance économique et démographique dans les principaux pays importateurs de produits laitiers. Deuxièmement, l'offre mondiale sera limitée par les réglementations environnementales, les conditions climatiques et la disponibilité limitée en terres dans les principaux pays exportateurs de produits laitiers, tels que la Nouvelle-Zélande, l'Union européenne et les États-Unis. D'autres facteurs devraient jouer un rôle important dans l'évolution future du marché laitier: les difficultés à attirer de la main-d'œuvre dans les exploitations laitières et à recruter des personnes qualifiées pour des travaux agricoles de plus en plus numérisés. Ce déséquilibre dans le commerce des produits laitiers devrait entraîner une augmentation des prix et pourrait donc conduire à une amélioration significative de la rentabilité des exploitations laitières.

Riassunto

Il settore lattiero-caseario globale ha vissuto un considerevole sviluppo negli ultimi 20 anni e si prevede che nei prossimi decenni sarà interessato da un radicale cambiamento. Il presente rapporto si prefigge di fornire una panoramica completa degli sviluppi del settore lattiero-caseario intervenuti negli ultimi 20 anni basandosi sull'esclusiva banca dati dell'International Farm Comparison Network (IFCN). L'obiettivo verte sulla produzione globale di latte, la domanda, la struttura delle aziende lattiero-casearie, i prezzi mondiali del petrolio, del latte e dei mangimi e il commercio di prodotti lattiero-caseari. Il rapporto presenta inoltre la prospettiva globale a lungo termine dell'IFCN per il 2030, il 2040 e il 2050. Con le sue analisi dettagliate degli sviluppi passati e di quelli ipotizzabili per il futuro del mercato lattiero-caseario globale, intende facilitare il processo decisionale ai portatori di interesse nel settore.

Il rapporto è basato sulla banca dati standardizzata dell'IFCN, che copre 125 Paesi pari al 99 % della produzione mondiale di latte. Gli standard nazionali dei dati possono variare notevolmente tra un Paese e l'altro, rendendo difficile il confronto diretto. Per assicurare una comparabilità tra Paesi, il Dairy Research Centre dell'IFCN, che collabora nella ricerca con partner internazionali, ha sviluppato metodi di standardizzazione per armonizzare le statistiche nazionali in materia e creare una banca dati standardizzata. Oltre ai metodi di standardizzazione, il Dairy Research Centre ha elaborato indicatori specifici, tra cui quello combinato sui prezzi mondiali del latte (IFCN Combined World Milk Price Indicator) e quello sui prezzi mondiali dei mangimi (IFCN World Feed Price Indicator) per monitorare la situazione dell'economia delle aziende e del settore lattiero-caseario globale.

Negli ultimi 20 anni la produzione mondiale di latte ha registrato una forte crescita nonostante le sfide globali emerse in questo periodo (p. es. la crisi finanziaria del 2007–2008 e la conseguente recessione, la pandemia di COVID-19 nel 2020–2022 o l'inflazione elevata nel 2021–2023). Dal 2000 al 2023 il tasso di crescita della produzione globale lattiero-casearia è risultato pari al 77 %, ossia il 2.5 % l'anno. La crescita è ascrivibile al progressivo incremento della domanda indotto da due principali fattori: aumento dei consumi pro capite (+36 %) e crescita demografica (+31 %). L'incremento della domanda riguarda in particolare le aree geografiche che non producono latte a sufficienza, tra cui Asia, Africa e America latina, dove lo sviluppo economico ha dato un forte impulso al consumo dei prodotti lattiero-caseari. In risposta alla crescita sostenuta della domanda, avvenuta contestualmente al notevole rincaro del greggio e dei mangimi a partire dal 2007, l'indicatore combinato IFCN dei prezzi mondiali del latte ha registrato non solo un forte aumento, ma anche una maggiore volatilità rispetto al periodo antecedente al 2007. Se dal 1981 al 2006 oscillava tra 10,7 e 24,1 USD/100 kg di SCM (Solid Corrected Milk, al 4% di grassi e al 3,3% di proteine), tra il 2007 e il 2023 è oscillato tra 26,1 e 53,4 USD/100 kg SCM. Si è rafforzato il nesso tra il mercato lattiero-caseario e quello del petrolio. La produzione lattiero-casearia continua a subire una profonda trasformazione a livello mondiale. L'evoluzione strutturale a lungo termine verso un numero minore di aziende di maggiori dimensioni è indotta dai progressi tecnologici, dalle forze di mercato e dalle esigenze di sostenibilità. Nel 2023 lo 0,2 % di tutte le aziende lattiero-casearie ha prodotto il 45 % del latte totale. La tendenza al consolidamento nel settore è proseguita nella maggior parte dei Paesi e si prevede che continui, plasmandone il futuro a livello mondiale.

In termini di prospettive, l'IFCN si attende che la crescita della domanda di prodotti lattiero-caseari superi l'offerta nei prossimi 30 anni. Si stima che entro il 2030 rimarrà insoddisfatta la domanda per 11 milioni di tonnellate di latte, con un ulteriore aumento previsto entro il 2050. Sono due i fattori più rilevanti che incideranno sul futuro sviluppo del mercato lattiero-caseario: in primo luogo, la domanda salirà a causa della forte crescita economica e demografica nei principali Paesi importatori, secondariamente l'offerta globale subirà restrizioni a causa delle stringenti normative per la protezione ambientale nei maggiori Paesi esportatori, tra cui Nuova Zelanda, Unione europea e Stati Uniti, nonché delle condizioni meteorologiche. Altri aspetti che potrebbero svolgere un ruolo importante nello sviluppo futuro del mercato lattiero-caseario sono le difficoltà ad attirare manodopera nelle aziende e a reclutare personale qualificato in grado di operare con una crescente digitalizzazione. Uno squilibrio nel commercio di prodotti lattiero-caseari è previsto e potrebbe portare a un miglioramento sostanziale della redditività del settore.

1 Introduction

Milk is one of the most produced and consumed agricultural commodities worldwide (Zolin et al., 2021). Dairy products are integral to a healthy diet, promoting improved nutrition and health outcomes (FAO, 2023; FAO et al., 2022). The global dairy sector serves over 7 billion consumers daily (Hemme, 2023). As the world population increases, the consumption of the dairy products is expected to rise. Consequently, global milk production in 2033 is forecasted to increase by 19% compared to the production level in 2023 (OECD/FAO, 2024). As a crucial component of the agri-food system, dairy production enhances the livelihood and economic opportunities of one billion people worldwide. This includes those who live on farms or work in the dairy chain, such as in feed and fertiliser companies, milk collection, processing, and retail (FAO, 2013; FAO et al., 2018). The dairy sector also contributes to poverty reduction (FAO et al., 2018; Hemme & Otte, 2010), zero hunger (FAO et al., 2020), good health and well-being (FAO, 2013), gender equality (Achandi et al., 2023; Doss et al., 2018; Mersha, 2017), and other UN Sustainable Development Goals (IDF, 2023; Wattiaux, 2023).

The growing awareness of the negative environmental impact of the dairy sector (Gerber et al., 2013; Rose et al., 2019), coupled with concerns about animal health and welfare (Ellis et al., 2009; Haas et al., 2019; McCarthy et al., 2017; Wolf & Tonsor, 2017), puts pressure on market players to improve its sustainability. The challenge for the sector is how to reduce its environmental footprint and address climate change while maintaining its positive contribution to global food security and poverty reduction (FAO & GDP, 2019). In this complex context, market intelligence is crucial for all players in the dairy sector.

International Farm Comparison Network (IFCN) is a global research network that provides dairy stakeholders with comparable data and outstanding knowledge (Appendix A). As the dairy world becomes increasingly globalised (Bojovic & McGregor, 2023; Davis & Hahn, 2016; Ohlan, 2014), staying aware of global trends and assessing the competitive position of dairy sector in their countries in comparison to others can better serve farmers, dairy-related companies, consumers, and policymakers. Researchers play a fundamental role in informing and supporting policymaking (El Benni et al., 2023) by equipping dairy stakeholders with scientific evidence targeted towards better economic and political decisions.

The goal of the present report is to provide a comprehensive overview of the global dairy market developments that occurred in the last two decades, relying on the unique market intelligence IFCN database. This database allows for a better country comparison and tracking of global trends in the dairy world. Our focus is on milk production, demand, dairy farm structures, world oil, milk, and feed prices, and the dairy trade. Furthermore, we present the IFCN global dairy outlook for 2030, 2040, and 2050. By providing detailed insights into past and possible future developments of global dairy market, this report aims to guide stakeholders in the dairy sector in their decision-making process.

2 IFCN data and standardisation methods

Our report relies on the standardised IFCN database, which covers 125 countries representing 99% of the world's milk production. National data standards may vary widely between countries, making direct comparisons difficult. To ensure cross-country comparability, the IFCN Dairy Research Centre, together with research partners from across the world, has developed standardisation methods that it uses to harmonise national dairy statistics and create a standardised database. The IFCN dairy sector database has been available since 1996. Our analysis primarily covers the period 2000–2023, with longer or shorter timelines in some sections. Besides standardisation methods, the IFCN Dairy Research Centre has developed specific indicators (such as the IFCN Combined World Milk Price Indicator and the IFCN World Feed Price Indicator) as well as standard classes to monitor the situation in dairy farm economics and in the global dairy market. In this section, we briefly present the standardisation methods developed by the IFCN and key IFCN global dairy market indicators. We also present a concise description of the methodological approach underpinning the IFCN outlook.

Quantity of milk

There are several different possible methods for bringing milk volumes or weights to a standardised basis for comparison. The IFCN applies the following key standardisations to ensure comparability between national data:

A) Conversion litres to kg. This metric ensures comparability between countries; if the specific unit in national statistics is in litres, it is adjusted in kilograms using a multiplier of 1.033 (1 litre = 1.033 kg).

B) Annualised data. In some countries (e.g. Australia, New Zealand, and India), milk production is based on seasonal milk production statistics. For example, the statistical record of milk production is organised by dairy season in Australia from July to June, in New Zealand from June to May, and in India from April to March. For those countries, seasonal milk production and price data are recalculated to annual data. In particular, in India, the annual 2022 milk production is based on a seasonal share of approximately 24% volume produced in the 2021/22 season (covering the milk production from January to March 2022) and 76% volume produced in the 2022/23 season (covering the production from April to December 2022).

C) Milk equivalents (ME). ME is a measure of the quantity of fluid milk used in a processed dairy product (Chite et al., 2005). Briefly, the calculation shows how much milk is used to produce dairy commodities. When estimating parameters such as per capita milk consumption, self-sufficiency, processing profile, dairy trade, etc., it is necessary to aggregate dairy commodities with different solid contents to obtain a meaningful and reliable unit of measurement. This occurs using so-called milk equivalent conversion factors. Among different possible approaches for the conversion into milk equivalents (IDF, 2004), the IFCN has selected the “fat and protein” method (Hemme & Blarr, 2004). The methods are applied to 25 single dairy commodities based on fat and protein content derived from the USDA National Nutritional Database (Hemme, 2023).

D) Solid-corrected milk (SCM). The SCM adjustment is used to standardise milk production and milk prices at the farm level to the same fat and protein content. Thus, all milk with natural content is converted into solid-corrected milk, and all farm gate milk prices with natural content are converted into solid-corrected milk. Solid-corrected milk is more compatible with ME, so production and demand are better aligned. Countries are depicted more accurately due to better comparable data (Hemme (2019, 2020, 2021, 2022, 2023).

Milk quality can vary in terms of milk solids, especially fat and protein content (Boelling & Hemme, 2017). For an accurate comparison of milk volumes between the countries, milk quantity measured in natural contents is converted into solid-corrected milk (SCM) with the aim of better reflecting the quantity of fat and protein produced. Both milk components are weighted equally. By definition, 1 kg SCM is 1 kg milk with 4% fat and 3.3% true protein. The majority of countries report in their national statistics crude protein[1] that should be converted to true protein. Non-protein nitrogen (NPN) is thereby assumed to account for about 0.19% of the “protein” in a crude protein value (Barbano et al., 1991). The SCM adjustment of milk volume occurs according to a two-step procedure. First, the protein content of the milk is converted into true protein (where necessary):

True protein% = crude protein% - 0.19%

Second, the milk is corrected for milk solid. The formula applied is as follows:

SCM = milk production × (fat% + true protein%)/7.3

The SCM quantities are correspondingly higher (lower) than the values of milk before adjustment, if the fat and protein contents are higher (lower) than the standardised solid content. The implications of the adjustment are illustrated in Table 1 for two countries: Ukraine and the Netherlands. As is obvious from this table, SCM data can be substantially different from national statistics based on natural content. This highlights how crucial this adjustment is in ensuring the comparability of national statistics.

[1] Crude protein, sometimes called total protein, is estimated from measuring the total nitrogen content in milk (ISO & IDF, 2014), which comes from both *protein* nitrogen (approximately 77% caseins and 17% whey) and *nonprotein* nitrogen (approximately 6%) sources such as urea and other low molecular weight nitrogen-containing substances (Lynch & Barbano, 1999). True protein reflects only the nitrogen associated with protein and does not include the nitrogen from nonprotein fraction (DePeters & Ferguson, 1992). As true protein is more reflective of the nutritional and manufacturing value of milk (Milk marketing, 1999), the shift from crude protein to true protein as the basis for milk pricing has been implementing in number of countries (e.g. the USA (VanRaden & Powell, 2000), France (Grappin, 1992), Australia (Rouch et al., 2007), and Canada (Saskmilk, 2018).

Table 1: Examples of the implications of SCM adjustment for two selected countries – Ukraine and the Netherlands

Country, year	Raw data	SCM adjusted	Difference
Ukraine, 2022			
Cow milk in mill t	7.7	7.0	-9.1%
Content	3.64% fat, 3.11% crude protein	4.0% fat, 3.3% true protein	
The Netherlands, 2022			
Cow milk in mill t	14.0	15.3	+9.3%
Content	4.42% fat, 3.55% true protein	4.0% fat, 3.3% true protein	

Source: Ukraine: State Statistics Service of Ukraine (https://ukrstat.gov.ua*);* Netherlands: Statistics Netherlands (CBS) (*https://www.cbs.nl*); Abbreviation: solid-corrected milk (SCM)

In many countries, milk price is dependent on milk quality, especially fat and protein content (Boelling & Hemme, 2017). The SCM adjustment is also used to standardise national farm gate milk prices, that is, to convert the prices per kg milk with natural content into prices per kg solid-corrected milk (SCM), that is, prices for one kg milk with 4.0% fat and 3.3% true protein. The conversion occurs as described in the formula below:

$$\mathbf{SCM_{price} = milk\ price/([fat\% + true\ protein\%]/\ 7.3)}$$

If the natural fat and protein contents of the national milk price are higher than 4% fat and 3.3% true protein, the national farm gate milk price with SCM-adjusted content will be lower than the national milk price. The implications of this conversion are illustrated in Table 2 for two selected countries: Ukraine and Switzerland.

Table 2: Example of milk price standardisation for two selected countries – Ukraine and Switzerland

Country, year	Raw data per 100 kg milk	Standardised data per 100 kg SCM adjusted	Difference
Ukraine, 2022			
Farm gate milk price in national currency (UAH)	1183.7	1303.3	+10.1%
Content	3.64% fat, 3.11% crude protein	4.0% fat, 3.3% true protein	
Switzerland, 2022			
Farm gate milk price in national currency (CHF)	70.0	68.3	-2.4%
Content	4.14% fat, 3.36% true protein	4.0% fat, 3.3% true protein	

Source: Ukraine: State Statistics Service of Ukraine (https://ukrstat.gov.ua) Switzerland: Milchstatistik der Schweiz 2022. (https://www.sbv-usp.ch/de/services/agristat-statistik-der-schweizer-landwirtschaft/milchstatistik-der-schweiz-mista); Abbreviation: solid-corrected milk (SCM), Ukrainian Hryvnia (UAH), Swiss Franc (CHF)

As mentioned previously, for a better economic analysis of the global trends in the dairy sector, the IFCN has developed two key indicators: the IFCN Combined World Milk Price Indicator and the IFCN World Feed Price Indicator, as well as the IFCN Standard Classes.

IFCN Combined World Milk Price Indicator. This indicator reflects the world market price level for milk and is derived from a selection of representative internationally traded dairy commodities. The calculation is based on the weighted average of three IFCN world milk price indicators: 1. SMP (Skimmed Milk Powder) & butter, 2. cheese & whey, 3. WMP (Whole Milk Powder) (Schröer-Merker & Nasrollahzadeh, 2012). The dairy prices used for calculating the IFCN Combined Milk Price Indicator are the Oceania commodity export prices (FOB port Oceania[2]) which are reported biweekly (USDA, biweekly reports). The weight attributed to each commodity group (Table 3) corresponds

[2] The calculation of world farm gate milk prices by organizations such as the FAO (2020), OECD (OECD/FAO, 2024), IFCN (Hemme, (2023), market research firms (e.g. Rabobank, 2024), dairy companies (e.g. Fonterra, 2011) involves globally traded dairy commodity prices from Free on Board (FOB) Oceania. The choice of using FOB port Oceania as a reference likely related to its significance in global dairy markets and its impact on milk prices. Oceania, particularly New Zealand and Australia, are major exporters of dairy products. Prices from Oceania are typically well-documented and publicly available, providing a reliable data source for dairy market analysis. Changes in export prices in Oceania can influence the dynamics of global dairy trade, making them an important benchmark for price calculation.

to its trade share in the world market and is updated quarterly. The formula for calculating the trade share of a specific dairy commodity group is:

$$\textbf{Trade share of a specific dairy commodity group in the world market} = \frac{\textbf{dairy exports (quantity) for specific dairy commodity group}}{\textbf{total dairy exports (quantity)}}$$

The regular update of the commodity weights allows accounting for changes in import demand and seasonal trade patterns, which makes the indicator more precise and market-oriented. In terms of interpretation, the IFCN Combined World Milk Price Indicator represents "*the milk price a milk processor would theoretically pay to its farmers, if it was selling its products on the world spot market and producing at standardised costs*" (Hemme, 2023).

Table 3: Trade shares of the dairy commodity groups considered in the IFCN combined milk price indicator per quarter

Year	Q1			Q2			Q3			Q4		
	SMP& Butter	Cheese& Whey	WMP	SMP& Butter	Cheese& Whey	WMP	SMP& Butter	Cheese& Whey	WMP	SMP& Butter	Cheese& Whey	WMP
2020	0.30	0.55	0.15	0.34	0.50	0.16	0.32	0.54	0.14	0.31	0.50	0.19
2021	0.32	0.50	0.18	0.33	0.51	0.17	0.26	0.64	0.11	0.27	0.59	0.14
2022	0.33	0.51	0.16	0.32	0.53	0.15	0.29	0.59	0.12	0.32	0.50	0.18
2023	0.34	0.52	0.14	0.33	0.51	0.16	0.32	0.56	0.12	0.32	0.55	0.13

Source: IFCN based on data from Global Trade Tracker (GTT); Abbreviation: skimmed milk powder (SMP), whole milk powder (WMP)

IFCN World Feed Price Indicator. Feed costs usually make up a high proportion of the total milk production costs and therefore play a crucial role in the profitability of a dairy business (Hemme, 2023). Recognising this importance, the IFCN has developed the IFCN World Feed Price Indicator to represent the world market price level for feed. The metric is based on the monthly world market prices for soybean meal (protein feed) and corn or barley (energy feed), taking into account their shares in a simplified standard world compound feed ration. It relies on an assumed composition of 0.3 kg soybean meal and 0.7 kg corn or barley per kg of compound feed. The monthly prices are sourced from the databases of the Investing.com financial platform and World Bank (price for soybean meal futures first contract forward[3] on the Chicago Mercantile Exchange; price for corn (U.S.), no. 2, yellow, FOB US Gulf ports[4]). The indicator is calculated on a monthly basis. To compare the compound feed costs in different countries, the aforementioned feed price indicator can be calculated for each country, considering the specificities of the country in terms of ration composition and relying on national price statistics or, if unavailable, IFCN estimates.

IFCN Standard Classes. Farm structures differ considerably between countries (Burchardi & Slabon, 2009; Hemme (2003, 2007, 2009, 2011, 2013, 2015; 2017, 2023); Hemme et al., 2005). To enable comparisons among all countries worldwide, a uniform definition of farm size and related classes is necessary. For this purpose, in 2011, IFCN introduced seven standard size classes relying on the cow herd size: 1–2, 3–10, >10–30, >30–100, >300–1000, >1000 cows. These standard classes are applied uniformly across all countries analysed. Three calculated variables—farm number, herd size, and milk produced in defined standard classes—allow for contrasting country-specific developments in a time series and derive future trends for the world, individual countries, or regions (Kühl & Wyrzykowski, 2013). Based on these size classes, three major types of farms have been defined by IFCN: household farms (1–2 and 2–10 cows per farm), family farms (10–30 and 30–100 cows per farm), and business farms (>100 cows per farm) (Hemme, 2017). *Household farms* are mainly found in developing countries with 1–3 cows or in developed countries with 10–30 cows. The dairy business is only a part of the family income. The key driver for a household farm is to produce milk for its own consumption and to sell part of it for a daily cash income (Hemme, 2018). In *family farms*, labour is predominantly provided by family members, with generating sufficient income for the family members being the key objective of these farms (Hemme, 2015). *Business farms*, characterised by their large scale, rely on employees to prioritise the attainment of the expected return on investment (ROI). Usually, a low share of production factors (land, labour, and capital) is owned by the business farm and therefore has to be paid (rents, salaries, and interests) (Hemme, 2015). The farm structure country database provides insight to better understand

[3] https://www.investing.com/commodities/real-time-futures

[4] https://www.worldbank.org/en/research/commodity-markets

the regional and national structure of dairy farms, to monitor the structural change pattern and dynamics, and to predict milk supply and usage patterns for farm inputs.

Dairy Outlook 2030, 2040, and 2050. The IFCN has been producing long-term global dairy outlooks annually since 2013 (Siwirska & Ajini, 2016). The major benefits of the outlook are cross-country standardisation and data comparability. The forecast results cover the total world milk production of more than 200 countries and include indicators such as supply, demand, dairy farm number, and farm size (Hemme, 2022). It relies on iterative country supply/demand equilibrium modelling, which is based on scenarios and related macro-economic assumptions. The modelling is based on the IFCN database and, more precisely, on 12 variables describing the milk supply and demand. First, the IFCN determines the two most relevant drivers of the dairy world, with which a matrix made of four scenarios is constructed (Wyrzykowski et al., 2018). Second, the IFCN selects the most probable scenario of the matrix. This scenario implies different assumptions. Based on these assumptions, "*an iterative world supply/demand equilibrium modelling process is run to determine a world price level that will allow milk production on a level to cover demand*" (IFCN, 2018). Some modelling assumptions are based on external sources, while others are derived from IFCN expertise. Although the official IFCN Outlook focuses on the most probable scenario, forecasts for other scenarios are possible by adjusting the assumptions based on the defined scenario before repeating the modelling process for new outputs. As economic and political conditions can change quickly, the IFCN updates its long-term dairy outlook yearly.

3 Development of the global dairy sector

Section 3 describes the status and development of the dairy sector in the last two decades, both globally and at the country level. Each of the sub-sections addresses different aspects of the dairy industry. Key areas include changes in milk supply and demand, farm structure, world oil, milk, and feed prices, and trade dynamics.

3.1 Milk supply

Considering the long-term development of the milk supply in the last two decades (Figure 1), it is evident that the global dairy sector has been characterised by sustained growth despite:

(i) the global macro-economic challenges that have occurred in this period, such as the 2007–2008 financial crisis (Mirzaei, 2023; Mittal, 2009; von Braun & Tadesse, 2012) and subsequent global recession (Breitenfellner et al., 2009), the COVID-19 pandemic of 2020–2022 (Acosta et al., 2021; Martin et al., 2023; Ritzel et al., 2022), and high inflation in 2021–2023 (see trading economics[5]); and

(ii) major changes in terms of agricultural policy related to the dairy sector (abolishment of the milk quota system in the European Union in 2015 (Jongeneel et al., 2023); reduction of dairy market support (Gouin & Trouve, 2020); new regulations such as the Pathways to Dairy Net Zero (GDP, 2022), the EU Farm to Fork Strategy (European Commission, 2020), Animal Welfare Acts in many countries).

From 2000 to 2023, milk production (including that of cow, buffalos, sheep, goat, and camel) increased from 564.8 million tons SCM to 999.2 million tons SCM, or 434.4 million tons SCM, which is equal to a growth rate of 77%. The substantial development of global milk production was driven by a strong increase in demand (see Section 3.2). Despite a steady increase in milk production across time, the yearly production gross rate, which amounts on average to 2.5% (18.5 million tons SCM) in 2000–2023, substantially varies between years (Figure 1). The lowest growth rate (1.3%) was observed in 2022. This shortfall in global milk production is attributable to the following regions: (i) India, due to challenge with the lumpy skin disease outbreak, low fodder availability that stemmed from drought in one part of the country, and heavy rains in other part; (ii) the EU, due to high input costs for the farmers together with adverse weather conditions; (iii) Brazil, due to dry weather conditions that led to a drop in fodder availability; and (iv) Oceania, due to the high rainfall, labour shortages and increased input costs (FAO, 2023b; Hemme, 2023). In 2023, milk output rebounded, returning to the average growth rate. This growth was principally driven by an increase in milk production in Asia (FAO, 2024).

[5] https://tradingeconomics.com/country-list/inflation-rate

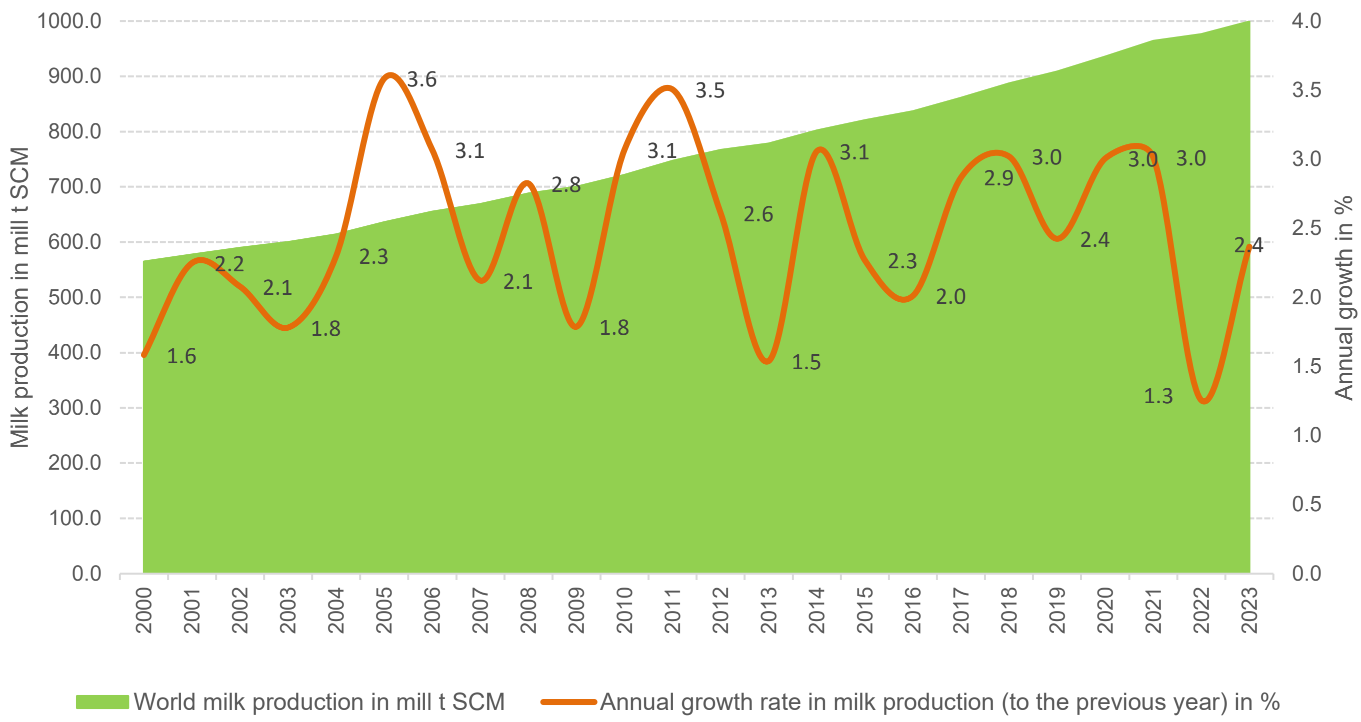

Figure 1: World milk production and annual growth
Source: IFCN standardised database; Abbreviation: solid-corrected milk (SCM)

The various countries (Appendix B) and regions showed very different speeds of development (Figure 2). Since 2000, South Asia, East and Southeast Asia, and Africa have increased their milk output by more than double, while other regions have been much slow. The three world largest producers by volume did not change from 2000 to 2023: India, 4.8%, the EU, 0.7%, and the United States, 1.7% annual production growth.

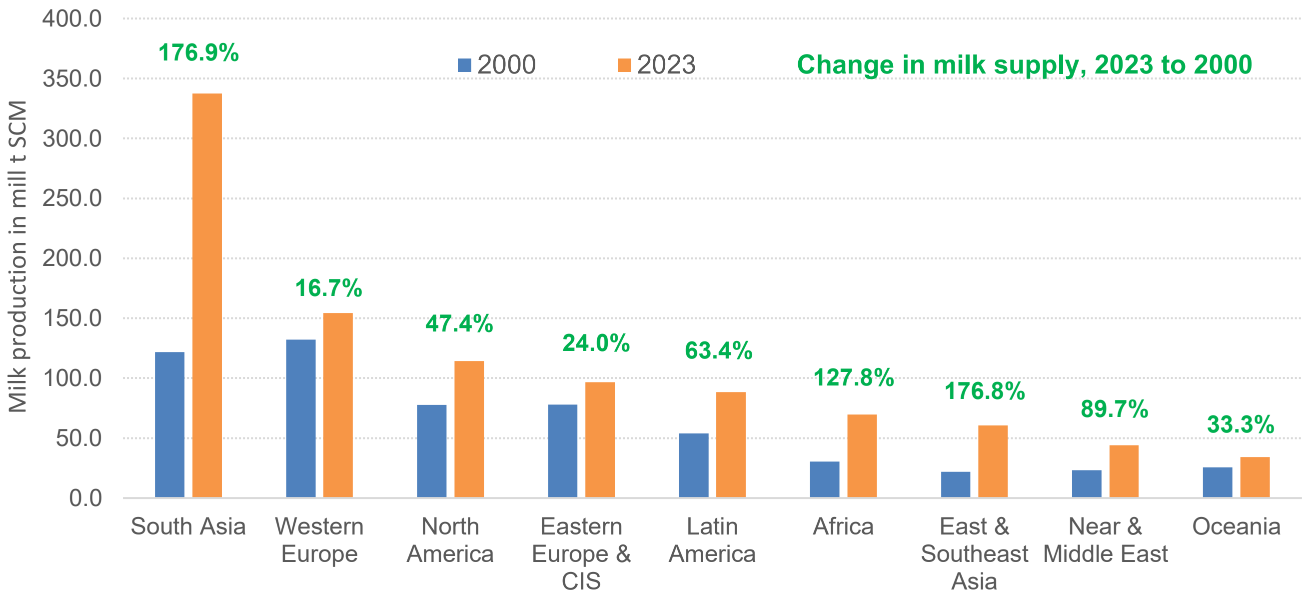

Figure 2: World milk production by region
Source: IFCN standardised database; Abbreviation: solid-corrected milk (SCM); Commonwealth of Independent States (CIS)

3.2 Dairy demand

In the period 2000–2023, the demand for dairy products constantly increased. The growth amounted to 77.6% (i.e. on average to 2.5% per year) (Figure 3). This development was driven by two main factors: rising per capita consumption (+36%) and a growing world population (+31%). The demand increased especially in developing countries, such as those in Asia, Africa, and Latin America, where economic development boosted the consumption of dairy products, which are perceived as beneficial to health (Headey, 2023; Hernández-Castellano et al., 2019). With the rise of a socio-political middle class and increasing purchasing power, consumers in transition and developing nations tend to shift towards higher animal product intake, particularly dairy foods (von Braun et al., 2023).

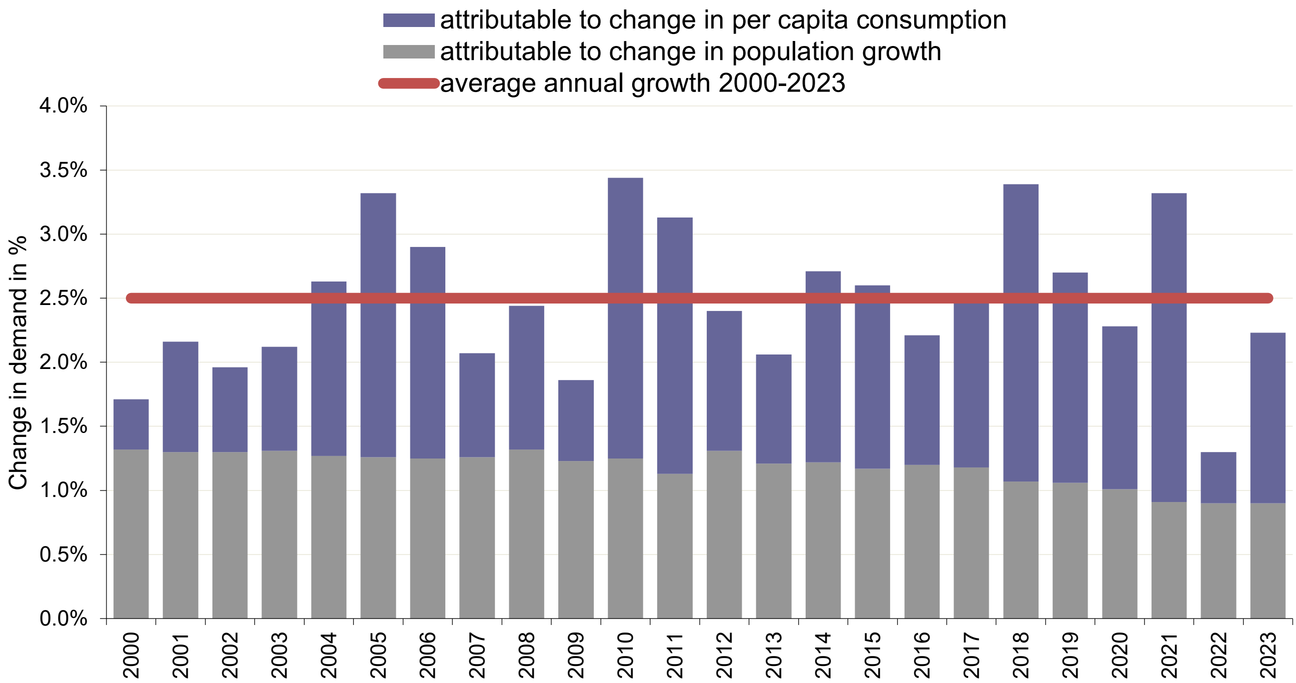

Figure 3: Dairy demand development
Source: IFCN standardised database; Calculation: Dairy demand: Milk production minus net stock changes

In our analysis of dairy demand from 2000 to 2023, similar to findings with milk production, 2022 was distinct from the other years (Figure 3). In that year, total demand increased by merely 1.3%, which was lower than the average yearly growth rate. As in previous years, this growth was driven by an increasing population (+0.9%), which was roughly equal to the growth rate in 2021. However, milk demand demonstrated the lowest growth in per capita consumption for the first time since 2000, increasing only by 0.4% compared to the previous year. There are several reasons for this development (Hemme, 2023). High inflation rates have affected consumer's purchasing power across most regions of the world, making dairy products less affordable. Record high milk prices at farm level were transmitted to the retail/consumption level especially in countries strongly connected to the world market. Less milk was produced on the global level. Hence, milk availability was limited by moderate growth in 2022. In 2023, a recovery in dairy demand was observed at +2.2%, which is attributable to the economy's improved resilience, subdued inflation, and enhanced demand in the main importing countries.

Regarding the major drivers of dairy demand, global milk consumption reached 126 kg ME per capita in 2023. The range was wide, varying from 6.9 kg ME in Nigeria to over 300 kg ME per capita per year in EU countries (Figure 4). In general, milk consumption per capita was higher in countries with developed economies and lower in developing countries, and appeared to be particularly low in tropical and subtropical climates. However, the latter countries showed a growing trend in per capita consumption, which contributed to the rise in world demand. For example, per capita consumption in China increased between 2000 and 2023 by 4.5 times to 38 kg ME due to urbanisation, "healthy" initiatives, and growing consumer income (Hemme & Shi, 2007; USDA, 2019). In India, milk consumption per capita doubled, reaching 185 kg ME (Figure 4). In low- and lower middle-income countries, most of the production was consumed in the form of fresh dairy products[6] (OECD/FAO, 2024). The share of processed dairy products in the overall consumption of milk solids is closely related to incomes, local preferences, dietary constraints, and urbanisation (OECD/FAO, 2023). Countries that already presented a high level of milk consumption per capita demonstrated not an increasing trend but rather a shift in consumption patterns towards more processed products (OECD/FAO, 2022).

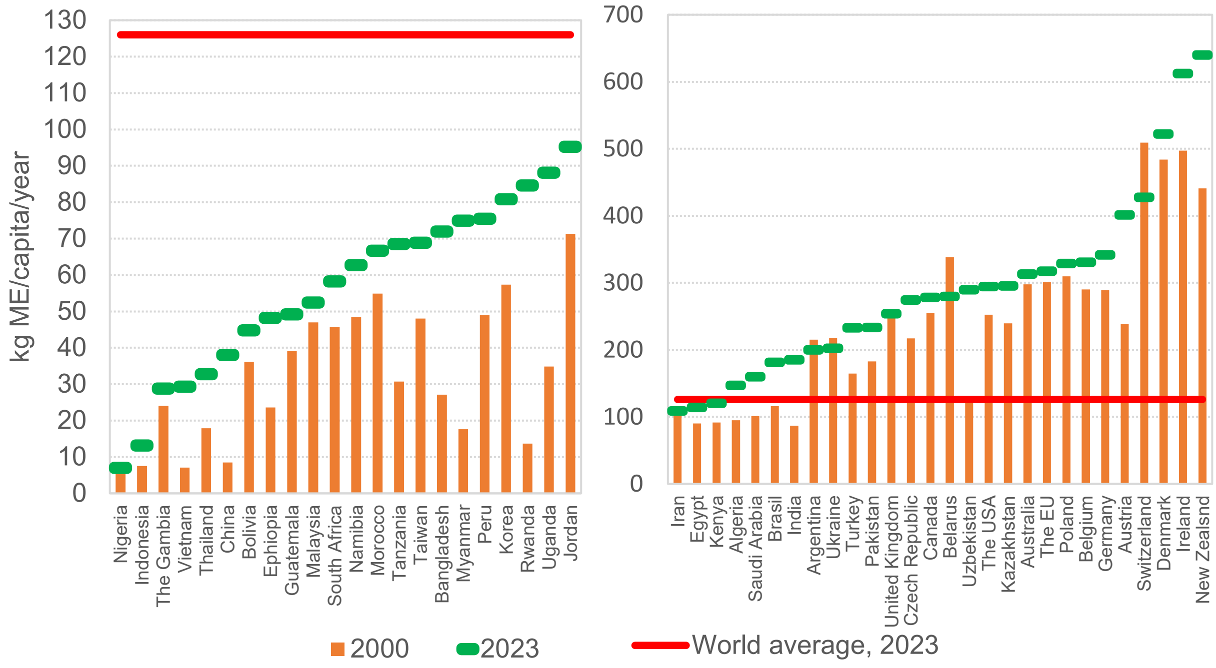

Figure 4: Change in dairy consumption per capita from 2000 to 2023
*Source: **Data:** IFCN standardised database; **Remark:** Countries have been grouped into the following categories according to their milk consumption in 2023: less than 100 kg milk equivalent (ME) per capita per year (left chart) and more than 100 kg milk equivalents (ME) per capita per year (right chart); **Calculation:** Dairy consumption = milk production of all dairy animals +import – export – net stock changes. Per capita consumption = national dairy consumption / population number*

As mentioned previously, the second factor explaining the strong growth in the global dairy demand is population growth, especially in some developing regions. Since 2000, population growth has primarily been observed in Southern Asia (+520 million) and Africa (+618 million) (IMF, 2023), making them important emerging dairy markets for the future. The future growth of world milk demand is expected to be driven to a greater degree by the increase in the per capita consumption of developing countries (OECD/FAO, 2024).

Unexpected adverse global events of climatic and geopolitical nature, which have become more frequent in recent years, are expected in the future to exert pressure on dairy demand in many countries to varying degrees, with emerging economies being the most vulnerable to short supply or disruptions in the supply chain.

3.3 Dairy farm structure: farm number, herd size, and milk production

Dairy farming is undergoing major structural transformations worldwide. These structural changes reveal both the strengths and weaknesses of farming systems. They may substantially affect milk supply as they relate to farm business profitability or, more generally, farm sustainability. Additionally, a country's farm structure plays a pivotal role in evaluating the social dimension of its dairy sector (Hemme, 2017). Therefore, it is crucial to understand these changes. In this section, we provide an in-depth analysis of the structure of the global dairy farming sector. We especially address the cross-country heterogeneity of dairy farm structure and its change in the last two decades, with a focus on selected countries.

[6] Fresh dairy products contain all dairy products and milk that are not included in processed products (butter, cheese, skim milk powder, whole milk powder, whey powder, and, for few cases, casein) (OECD/FAO, 2023). They are unprocessed or only slightly processed and include fresh liquid milk, pasteurised, homogenised, sterilised or UHT milk, fermented milks, yoghurts, fresh cream, milk-based drinks, ice cream, and others.

3.3.1 Number of dairy farms

The analysis of changes in world dairy farm numbers since 2000 revealed two distinct periods (Figure 5). Between 2000 and 2012, the number of dairy farms globally grew at an annual rate of 1.8%, increasing from 100.5 million to 123.5 million. However, this trend reversed in 2013. Since then, global dairy farm numbers have been declining, at an average annual rate of 1.2%. This decrease is a result of the consolidation process in the dairy sector (Hemme (2017, 2019). Despite this global decline, we observed two opposite trends. In developed countries and some developing countries, dairy farm numbers are decreasing, whereas in most developing countries, they continue to increase (Appendix C). This can be explained by household farms quitting the business in developed countries, thus reducing the overall number of farms, whereas in many developing countries, population growth has led to an increase in the number of smallholder farmers (Hemme (2021, 2023). Since 2013, the most significant decreases in farm numbers have been observed in China (-87.1%), the Ukrainian formal sector (excluded households) (-56.3%), the EU (-46.2%), and the United States (-44%) (Appendix C).

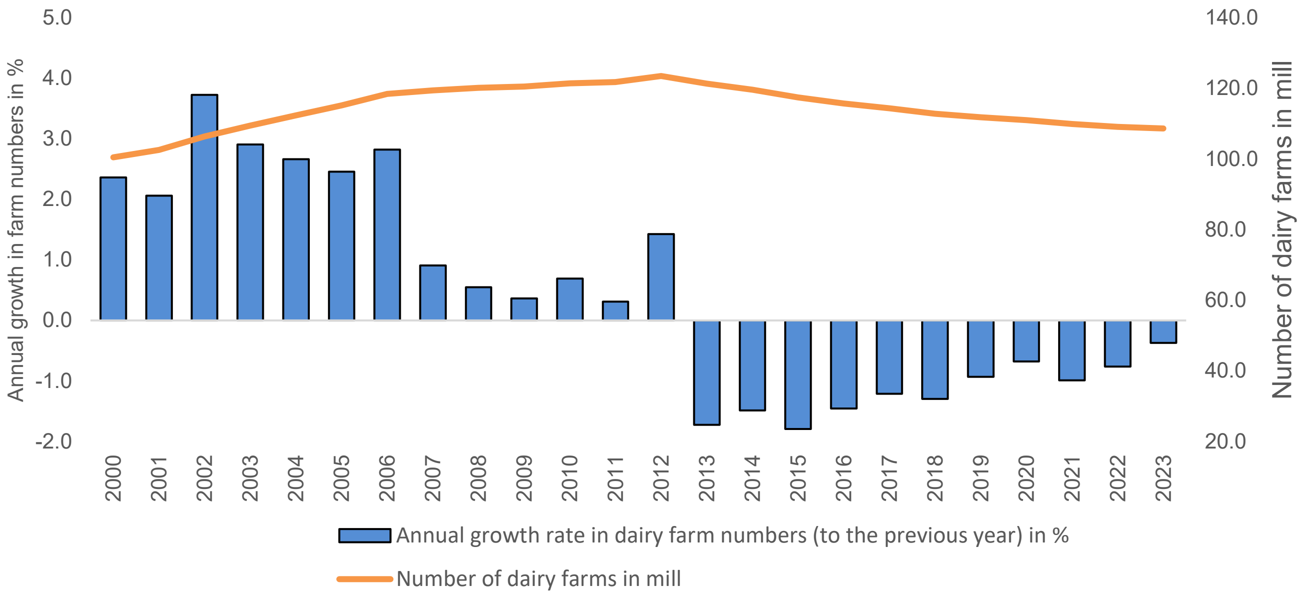

Figure 5: World dairy farm numbers and annual growth
Source: IFCN database

In 2023, the total number of dairy farms in the world was estimated to be 108.7 million (Appendix C). Approximately 61.3% of all dairy farms were located in India (66.6 million), with an additional 6.2% in Pakistan (6.7 million), making them the two countries with the highest farm numbers. The next places in the country ranking by number of dairy farms are held by Bangladesh, Kenya, Uzbekistan, Ethiopia, and Nepal, with dairy farm counts ranging between 1.8 and 3.9 million each. By comparison, the dairy farm numbers in the United States and New Zealand appear relatively small, with 26900 and 10600 farms, respectively. Countries with a huge number of farms (such as India or Pakistan) encompass a large share of very small subsistence farms, whereas the dairy sector of countries with much smaller farm counts (such as the United States or New Zealand) is made predominantly of large commercial farms. Thus, there is an indirect link between a country's dairy farm counts and the development stage of its dairy chain. Countries with a huge number of very small dairy farms tend to be typically not self-sufficient in dairy products, while those with a small number of large dairy farms tend to be self-sufficient and even generate a surplus of milk traded on the world market (see and compare Appendix C and Appendix L).

3.3.2 Farm size (in cows per farm)

The dairy farming sector consolidation process observed since 2013 has led to a decrease in farm counts and a simultaneous increase in farm size. The average farm size (in number of cows) in 2023 and the change in farm size between 2013 and 2023 are provided for the different regions of the world in Figure 6. As is obvious from this figure, increasing trends in farm size were observed in all regions except Latin America and Africa. However, the magnitude of the average increase in farm size differed substantially according to geographical area. East and Southeast Asia experienced the highest relative growth rate (+174%), despite an average farm size of 12 cows. North America and Western Europe also substantially increased farm size by 68% and 42%, respectively, reaching average herd sizes of 289 cows and 72 cows. Oceania, which was characterised by the highest average farm size among all regions, registered an average farm size growth of 15%. The average farm size in Africa remained nearly stable (+ 1% increase between 2013 and 2023).

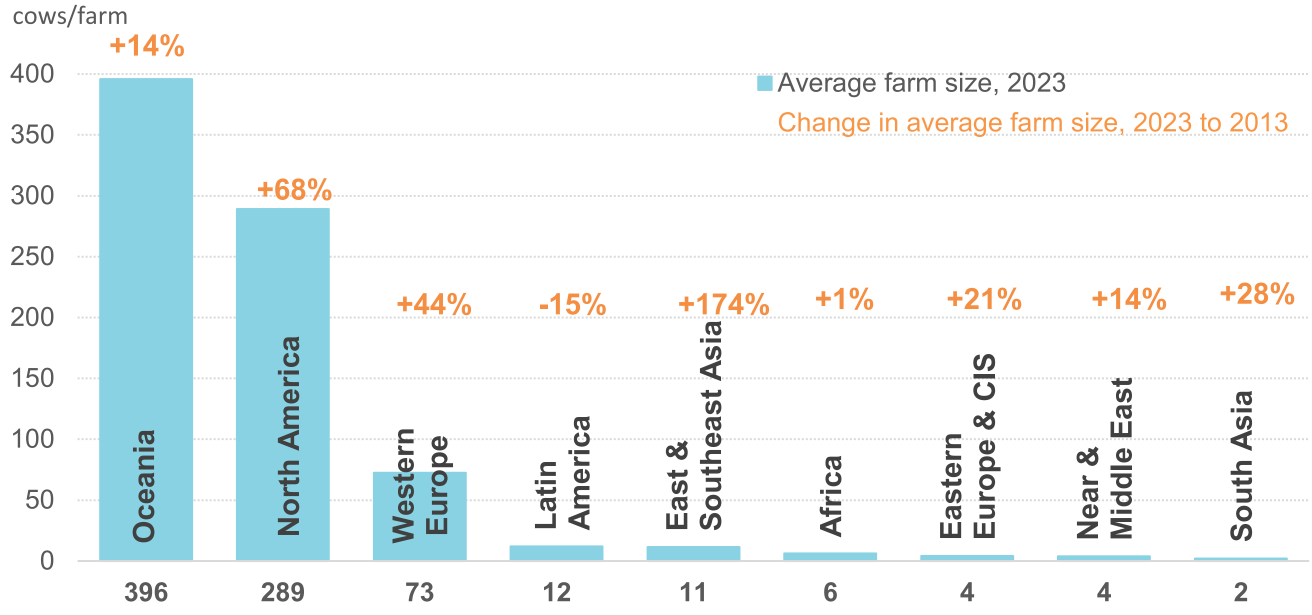

Figure 6: Global average dairy farm size
Source: IFCN Farm Structure Data; Abbreviation: Commonwealth of Independent States (CIS)

In 2023, the world average dairy farm size was 3.5 cows, with a very broad range between countries, from, for example, 1.5 cows in Rwanda to 441 cows in New Zealand (Appendix C). Globally, 64% of the dairy herd was maintained on household farms with fewer than 10 cows, representing 97% of all dairy farms and producing 38% of the total milk. The share of household farms was particularly high in most countries of Asia, Eastern Europe, the CIS, and in many African nations. At the global level, roughly 17% of all cows were in the category of family farms, which had 10 to 100 cows, accounting for 3% of dairy farms and producing 17% of the total milk. Family farms were prevalent in Western Europe and Latin America. The remaining 19% of cows were housed on business farms with more than 100 cows, constituting only 0.2% of all farms, yet accounting for 45% of the milk quantity produced at the global level. Business farms were primarily located in Oceania and North America. In 2023, there were 21 countries, compared to 13 in 2013, with an average farm size of more than 100 cows.

3.3.3 Milk production in different size classes

Figure 7 shows changes in the relative importance of the different farm structure segments—that is, size classes—in terms of the share of global milk production in the last two decades. The class with more than 1000 cows grew globally at the fastest pace in this regard. The relative importance of the size class between 300 and 1000 cows also increased in the last two decades, although at a slower pace than the class with more than 1000 cows. The global milk production share accounted for by the size class between 100 and 300 cows remained almost constant in the 20 years of the study period. Whereas the relative importance of the size class between 10 and 100 cows steadily decreased since 2000, the size class between 2 and 10 cows gained substantial importance in terms of global milk production share. Finally, the relative contribution of the size class between 1 and 2 cows remained stable since 2000.

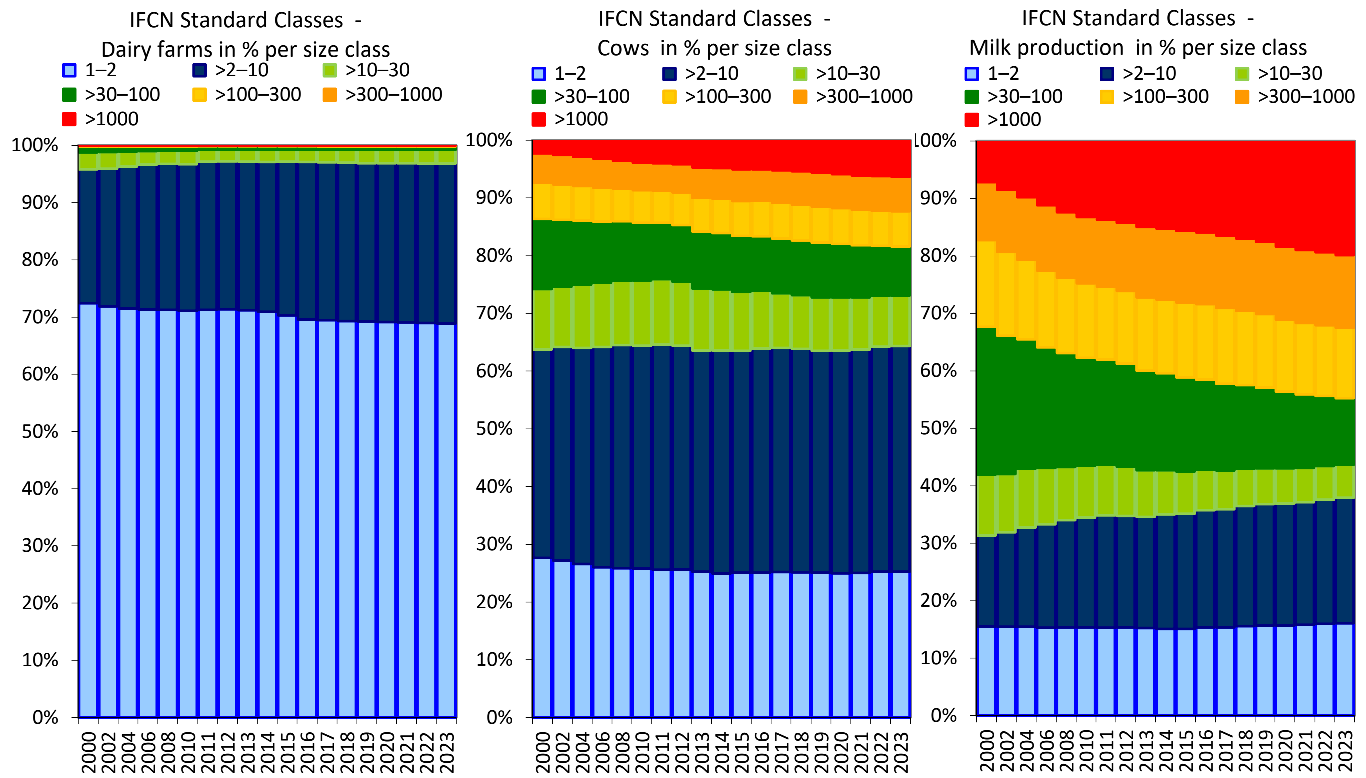

Figure 7: Global farm structure overview
Source: IFCN Farm Structure Data represented according to the IFCN standard classes

Among the top 10 largest dairy farms globally, half were situated in China, with the remainder located in the United States and Saudi Arabia. Together, these top 10 largest dairy farming companies accounted for 1.1% of the world's milk output in 2018. The biggest dairy farm at the world level was *Modern Dairy* from China, which recorded 134,315 dairy cows and produced 1.28 million tons of milk in 2018 (Kocic & Hemme, 2020).

Structural changes also varied widely between countries. In the case of the major exporter ***New Zealand***, for the period 2000–2023, the role of big farms increased (Appendix D). The share of dairy farms with between 300 and 1,000 cows increased from 20.1% in 2000 to 57.6% in 2023. Correspondingly, the proportion of cows on these farms rose from 35.8% to 82.5%, and milk production increased from 36.2% to 82.6%. Notably, farms with fewer than 10 cows were not observed in this country.

In ***the United States***, the proportion of farms with herds larger than 1,000 cows increased from 19.1% to 69.4% in 2023, with the corresponding share of milk production rising from 24.3% to 67.2% (Appendix E). Interestingly, in 2023, 67.2% of the milk was produced by only 6.4% of dairy farms in the country.

In ***Germany***, the share of farms with a herd size of less than 100 cows decreased from 97.1% in 2000 to 79.1% in 2023, proving the domination of family farms (Appendix F). Furthermore, cows held at this farm size and milk production steadily decreased from 79.2% to 40.7%. In 2023, the size class of 100–300 cows encompassed the largest share of cows (39.3%) and milk production (39.3%), a position held in 2000 by the size class of 30–100 cows, which accounted for 50% of all cows and whole milk production. In the EU-27, the average farm size was 26 cows per farm in 2023, compared to 7 cows in 2000.

In ***Switzerland***, two farm size classes (10–30 cows and 30–100 cows) dominated for the period 2000–2023 (Appendix G). In 2023, these two classes covered 89.6% of farm numbers, maintained 93.6% of cows, and produced 93.6% of milk. Structural change occurs more slowly in Switzerland than in neighbouring EU countries (Zorn, 2020). Nonetheless, large dairy farms gained importance. Whereas in 2000, the share of milk produced on farms with 30 to 100 cows was 22%, in 2023, it was 48%. It is worth noting that this country had no farm size classes of 1–2 cows or more than 300 cows.

In ***China***, structural changes occurred quite rapidly, with an increasing number of cows and a share of milk production on large-scale farms. In particular, the proportion of cows on farms with more than 100 cows increased from 13.4% to 78.3% between 2002 and 2023; milk production accordingly increased from 78.3% to 84.2% (Appendix H). The share of cows held on farms with more than 1,000 cows increased from 3.2% to 45%, with their milk production increasing from 20.8% to 52%. However, the share of farms in the largest farm class in 2023 was only 0.8%. The smallest farm class (1–2 cows) accounted for 57.8% of the share and produced 6.7% of all milk.

Ukraine exhibited a specific structure of milk production. On the one hand, the country had around 800,000 households, each with 1–2 cows. On the other hand, there were commercial dairy farms, represented by registered entities, with an average herd size of 300 cows, starting from 1,000 hectares (Appendix I). Small households contributed significantly to the overall milk supply, producing more than 60% of the milk in the country. These families were engaged in traditional milk production for their own consumption and for local markets. However, their share of milk production gradually decreased, mainly due to the ageing of farmers. The formal sector primarily supplies dairy processors and therefore consumers. Structural changes in commercial dairy farms occurred rapidly during the study period, with farms holding 500 or more cows becoming the main group, encompassing around 60% of dairy cows and producing about 70% of the milk in the official sector (Hemme, 2023, p. 193).

In ***India***, there were hardly any structural changes (Appendix J). More than 95% of Indian milk was produced by household farms with fewer than 10 cows. Notably, despite the strong dominance of very small farms, all size classes were observed in this country. For example, farms with 30–100 cows, which represented only 0.08% of all farms, produced 4.5 million tons of milk, or 1.8% of the total milk production. This amount was equivalent to milk production in Belgium or Ethiopia.

In ***Argentina***, dairy farms with more than 100 cows constituted a significant proportion of the industry, accounting for 75.7% of farms, 95.3% of cows, and 82.3% of milk production. These structural changes were characterised by relatively slow dynamics, especially since 2008 (Appendix K).

The speed of structural changes in dairy farming depends on various factors. It is mainly driven by economies of scale. The shift towards large-scale, industrialised farming operations has led to lower average production cost per unit of milk produced, increased efficiency and productivity, and marginalisation of smaller farms that struggle to compete with economies of scale (MacDonald & Newton, 2014; MacDonald et al., 2020). The adoption of cutting-edge technologies, such as robotic milking systems, herd management software, precision agriculture tools, and biotechnology streamline operations, reduce labour costs, and enhance production efficiency, further driving the structural evolution of the dairy sector. Rural depopulation and the ageing farming population result in a declining number of family farms, as younger generations migrate to urban areas for better economic opportunities, leaving fewer successors to continue farming traditions. The so-called deagrarianisation (Hebinck, 2018) creates conditions for the further consolidation of dairy farms, thus promoting industrialised farming. These processes can have a destructive effect on agriculture-based modes of livelihood, diminishing the role and functions of smallholder farming in maintaining the vitality of their countryside in accordance with local and cultural traditions. In the context of a historically strong connection between small farmers and local rural communities, structural changes towards fewer and larger farms have weakened the socio-ecological and socio-cultural functions of agriculture (Besser et al., 2017; Nowack et al., 2023). Market dynamics, such as consumer preferences, demand for specific dairy products (e.g. organic, low-fat, plant-based alternatives), and global trade patterns, drive structural changes in the dairy sector. Farms that respond swiftly to market shifts remain competitive. Other factors, such as increasing societal expectations in terms of sustainability and resulting regulations on environmental and animal welfare standards, may accelerate structural change. Some factors, such as high land prices, input factors availability, quotas, or other state regulations, may slow down or halt structural change.

The role of large farms is projected to remain worldwide, while less competitive smaller dairy farms are expected to exit the market (Bojovic & McGregor, 2023; Britt et al., 2018). The expected future decrease in the share of small-scale and family farming is inevitable and an evolutionary outcome of past and contemporary processes of agrarian transformations. The structural trend towards the disappearance of small farms will hardly be reversible. However, globally, the quantitative and qualitative importance of smallholder farming, especially in developing countries, will remain significant due to its crucial role in feeding the population, reducing poverty and hunger, ensuring food security, and protecting landscape features and biodiversity (Ricciardi et al., 2021; Samberg et al., 2016).

3.4 Global trends in oil, milk, and feed prices

Milk prices are affected by feed and oil prices. In this paragraph, we analyse the price development of these three commodities, with a particular focus on the linkage between the oil and agricultural commodities markets.

3.4.1 Comovement and synchronisation of oil, milk, and feed prices

The trends in the long-term annual price development of oil, milk, and feed show more or less simultaneous rises and falls (Figure 8). All prices followed a similar pattern, with comparatively low price levels from the 1980s to the beginning of the new millennium. Afterwards, all three monitored prices left their old price ranges, showing strong fluctuations. The world milk price ranged from 11 to 53 USD/100 kg SCM in the period 1981–2023, the feed price ranged from 11 to 37 USD/100 kg, and the oil price ranged from 13 to 112 USD/barrel (Figure 8). The volatility between years has been accelerating since 2007, with significantly higher volatility ranges.

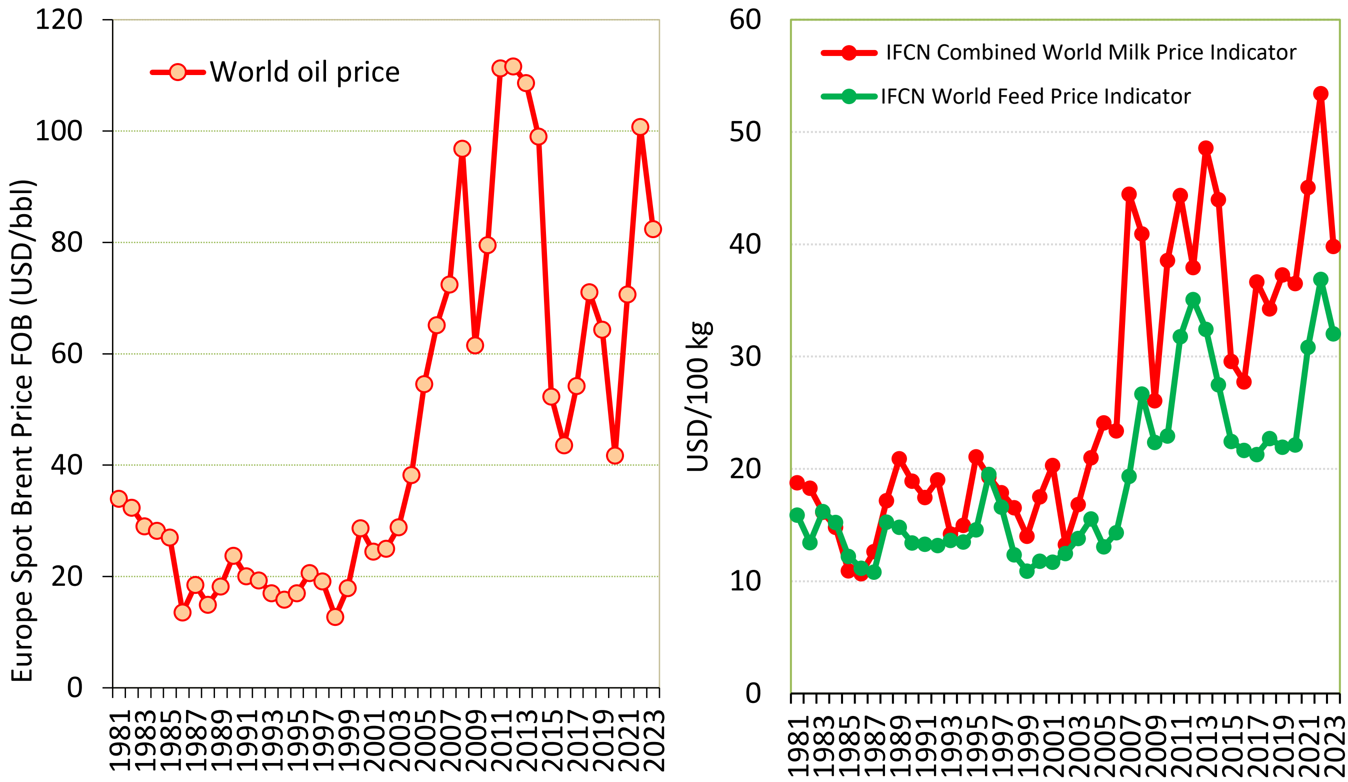

Figure 8: Evolution of oil, milk, and feed prices, 1981–2023
Source: Oil prices: Energy Information Administration and Association of the German Petroleum Industry; milk and feed prices: IFCN Combined World Milk Price Indicators (in USD/100 kg solid-corrected milk (SCM) and IFCN World Feed Price Indicators

The integration of advanced agricultural technologies and the expansion of global trade have significantly increased the oil dependency of the world's food system. This dependency has, in turn, heightened the susceptibility of food prices to fluctuations in oil prices. As evidenced by studies by Al-Maadid et al. (2017), Dahl et al. (2020), Roman et al. (2020), and Adeosun et al. (2023), there has been a pronounced transmission of volatility between the oil and food markets.

Sudden disruption in oil availability, whether due to geopolitical conflicts, shifts in supply and demand, or economic crises, profoundly affects the food system at all levels. This has an impact on the production processes on farms, the transportation and distribution networks, and, ultimately, the availability and prices faced by consumers. Historical instances of significant oil price spikes underscore this vulnerability. For example, the 1973 oil embargo and the 2007–2008 financial crisis both demonstrated how interconnected and sensitive the food and oil markets are (Abbott et al., 2009; Zulkifli & Haqeem, 2022). In 2022, Russia's invasion of Ukraine created an energy crisis of unprecedented scale and complexity, reminding the world of the fragility and unsustainability of the current energy system (WTO, 2023). Energy turmoil has led to a surge in oil prices. This shock and the resulting supply chain disruption increased the synchronisation of energy, grain, and fertiliser prices at the global level (Ihle et al., 2022). For dairy farms, this caused the higher costs of milk production triggered by the extraordinary input prices.

In 2006, the International Energy Agency reported that the world had reached the peak rate of crude oil production and concluded that scarcity and high prices were here to stay (OECD & IEA, 2006). Due to the continuing depletion of world hydrocarbon reserves, the new reality is that once oil prices increased, they did not return to the previous lower level observed before 2006. Despite ambitious policies aimed at the development of renewable energy sources (including energy source diversification and energy security enhancement) in many countries, the energy transition requires time. In most global energy scenarios, hydrocarbons (oil, gas, coal) are expected to still account for more than 50% of the total primary energy demand in 2050 (Raimi et al., 2024). Erik Elgersma, founder and director of Strategic Analysis Services BV, summarised, “No matter how hard we work in the dairy industry to combat CO2 emissions, there is one thing to be learned: fossil fuels will be with us for the times to come” (IFCN Dairy Conference, 2023).

3.4.2 Paradigm change in the global dairy market since 2007

Considering the period 1981–2006, the world milk price ranged between 10.7 and 24.1 USD/100 kg SCM, showing only limited fluctuations within individual years (Figure 8). Volatility started to increase in 2007, when prices rose from 23.4 to 44.5 USD/100 kg SCM, indicating a 190% increase in one year. This sharp increase was driven by the high global demand for milk, coupled with low stock levels, as well as higher oil and feed prices (Hemme, 2009; Slabon & Hemme, 2008). It marked a paradigm shift in the global dairy market from being supply driven to more and more demand driven. Since 2007, the world milk price development has fluctuated strongly, ranging from 26.1 to 53.4 USD/100 kg SCM. Despite the many drivers of the world milk price, the main cause of its strong fluctuation in the last two decades has been linked to global milk production and demand. The imbalance between these variables, caused by various interconnected factors (macroeconomic factors, environmental issues, conflicts, etc.), has led to a cyclical development of world prices with drops and recoveries. In particular, after a new historical record for the monthly world milk price set at 63.4 USD/100 kg SCM in April 2022, which was driven by supply constraints combined with firm demand (Kozak et al., 2022), it declined to 36.4 USD/100 kg SCM in September 2023, attributed to milk production recovery and higher dairy commodity availability on the market, which pulled prices down. The first months of 2024 showed an increase in world milk prices, reaching 44.5 USD/100 kg SCM in June 2024 (Figure 9).

The same volatility trends were observed in world feed prices. After remaining at a low level from 1981 to 2006, averaging 13.8 USD/100 kg, the world feed price began to fluctuate widely (Figure 8). From 2007 to 2023, the world feed price averaged 26.5 USD/100 kg, ranging from 19.3 to 36.9 USD/100 kg annually, and from 17.3 to 39.5 USD/100 kg on a monthly basis (Figure 9). In April 2022, similar to the world milk price, the world feed price reached a historical peak of 39,5 USD/100 kg, which was 22% higher compared to 2021. Apart from rising oil prices, the global feed market faced limited availability of grain and oilseeds due to the war in Ukraine (He et al., 2023). Moreover, weather conditions across the globe in 2022 had a negative impact on feed production, resulting in a lower-than-expected harvest (IFCN, 2023). In 2023, the world feed price significantly decreased by -13%, but it was still above the average feed price level in 2021. From January to July 2024, the price was mostly decreasing due to the higher feed production and weaker demand and growing competition for export between the US, South America and the Black Sea region.

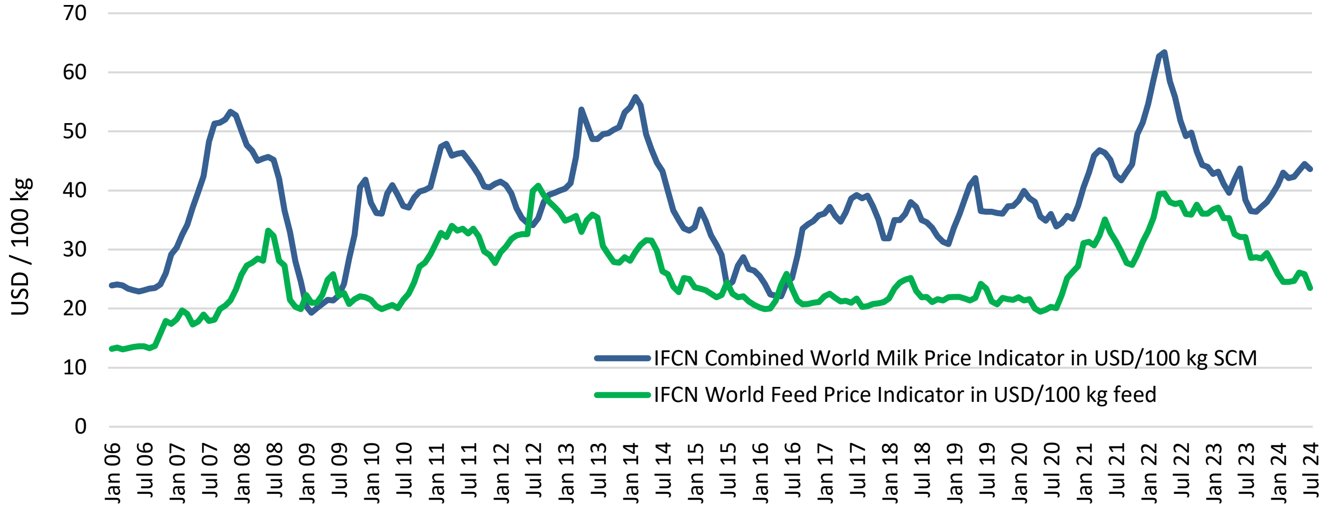

Figure 9: World milk and feed monthly prices
Source: IFCN monthly calculated World Combined Milk Price and World Feed Price; Abbreviation: solid-corrected milk (SCM)

The markets for dairy or—more generally—agricultural commodities and the oil market are also linked via biofuels (Carvahlo et al., 2007; Paris, 2018). Higher oil prices and policies aimed at developing renewable energy sources have boosted the production of biofuels. Feed and food production is therefore increasingly competing with biofuel production for the utilisation of agricultural land (UN, 2014). This contributed to the sharp milk and feed price rise observed after 2006. In addition, feed prices and thus the costs of milk production are also driven by weather effects. Adverse weather conditions lead to lower feed harvest, which in turn results in higher feed prices, affecting mainly dairy farms based on production systems that rely strongly on compound feed.

Milk and feed prices play a crucial role in shaping the economics of dairy farming. In milk production, feed accounts for up to 70% of the total input costs for dairy farms (Alqaisi et al., 2019). The year 2022 was characterised by record-high milk prices nearly worldwide on the one hand and high production costs on the other (Hemme, 2023). Nevertheless, the increases in costs were less than the upturn in the world milk price, which allowed many farmers around the world to end the year with substantial farm incomes. Based on the IFCN farm economic dataset, all world regions showed a positive entrepreneur's profit, with Western Europe and North America benefitting the most (Figure 10).

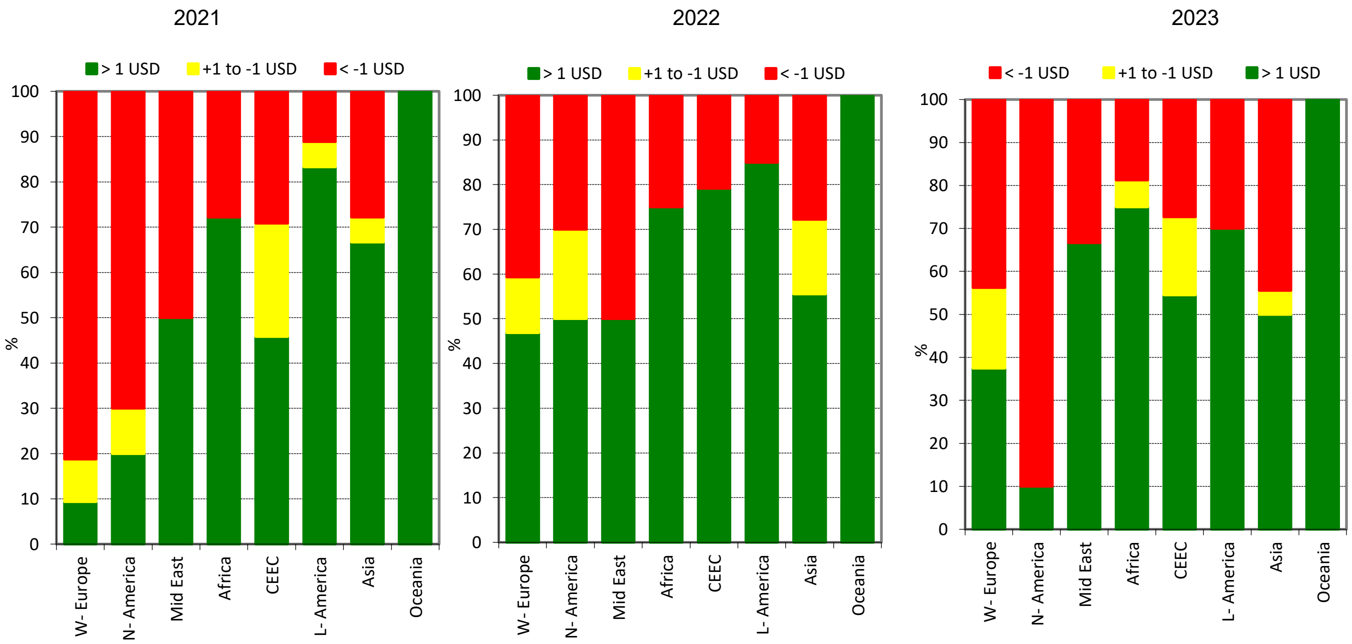

Figure 10: Distribution of dairy farms according to entrepreneur's profit class, 2021, 2022, and 2023
Source: IFCN database; Explanation: The entrepreneurs' profit shows whether the farms are able to cover their full economic cost without decoupled payments; Calculation: Entrepreneurs' profit is calculated as total returns (without decoupled payments) minus the full economic costs (costs from profit & loss account including depreciation plus opportunity costs) of the dairy enterprise; Abbreviation: Central and Eastern European Countries (CEEC)

A positive entrepreneur's profit indicates that a farming system does not depend on government support (decoupled subsidies) and that the system is financially sustainable. In 2022, a record number of farms worldwide made a positive entrepreneur's profit, compared to 2021. In 2023, farm economics worsened after an exceptionally good year (Figure 10). The reasons were lower milk prices and high costs that have changed only slightly since 2022. The decline in entrepreneurial profit was 7.2 USD/100 kg SCM for North America, 2.0 USD/100 kg SCM for Central and Eastern European Countries (CEEC), 3.3 USD/100 kg SCM for Latin America, 1.0 USD/100 kg SCM for Asia, and 0.4 USD/100 kg SCM for Western Europe. Africa and Oceania even managed to improve their entrepreneurial profit, with increases of + 1.7 and + 1.4USD/100 kg SCM, respectively (Hemme, 2024, to be published).

Considering the high volatility in the oil, dairy, and feed markets, farmers' ability to adapt quickly to changing circumstances (resilience) will be a key driver of future success.

3.5 Dairy trade

Trade in dairy products has become increasingly relevant in the course of globalisation, connecting markets around the world but also leaving them more vulnerable to disruptions. Many countries are unable to meet their growing dairy product demand, while others are generating a surplus (Appendix L). As shown in Table 4, a small number of surplus countries are supplying to a large number of deficit countries. Trade volumes of dairy products increased by 70% (excluding EU intra-state trade) from 2006 to 2023, while their share on milk production remained stable over the years, at about 10%. The list and ranking of the biggest dairy exporters and importers did not change much for the last decade or more, with the exceptions of (i) the United States, which moved from a net importer to a net exporter; (ii) Australia, whose net trade surplus substantially declined; and (iii) Belarus, whose surplus increased. Another interesting fact is that the net trade deficit of the most important net importers increased between 2006 and 2023.

Table 4: Top-10 dairy net export and net import countries

Country	Net trade surplus in mill t ME				Country	Net trade deficit in mill t ME			
	2006	2011	2021	2023		2006	2011	2021	2023
New Zealand	15.4	19.0	25.2	23.6	China	-1.5	-3.6	-16.9	-11.4
EU-27	11.3	12.5	19.1	19.9	Russia	-2.8	-3.2	-4.5	-4.1
US	-0.2	3.7	6.4	5.6	Algeria	-2.0	-2.5	-2.8	-3.0
Belarus	1.8	2.4	4.8	5.0	Mexico	-2.7	-2.3	-2.8	-2.7
Iran	0.0	0.0	0.4	2.2	Saudi Arabia	-0.5	-0.3	-1.8	-2.4
Argentina	2.4	2.7	2.7	1.8	Japan	-1.9	-2.1	-2.6	-2.4
Uruguay	0.8	1.1	1.5	1.5	Korea	-0.7	-1.2	-2.2	-2.2
Australia	4.0	2.6	1.5	0.5	Indonesia	-1.0	-1.5	-2.2	-2.2
India	-0.1	0.0	0.5	0.2	Philippines	-0.9	-1.2	-2.1	-1.9
Turkey	-0.1	0.1	0.6	0.2	Malaysia	-1.0	-0.9	-1.7	-1.7

Source: IFCN trade database - GlobalTradeTracker (GTT) provides monthly trade data for 26 dairy commodities at a level of 6-digit Harmonized System (HS) codes converted with their respective milk equivalents (ME) and summed up

Policies, changes in demand or supply patterns, and economic crises, especially in major dairy importer and exporter countries, are the main drivers influencing global trade developments, with a huge impact on world milk prices. As an example of policy implications, the Russian import ban on EU dairy products in 2015 led to a decrease in total global dairy imports and thus demand, which led to a significant drop in the world milk price (Hemme, 2016; Kraatz, 2014). In 2022, the world dairy trade declined for the first time since 2006, primarily due to reduced import demand from the world's largest dairy importer, China, alongside continued supply chain disruptions (Figure 11).

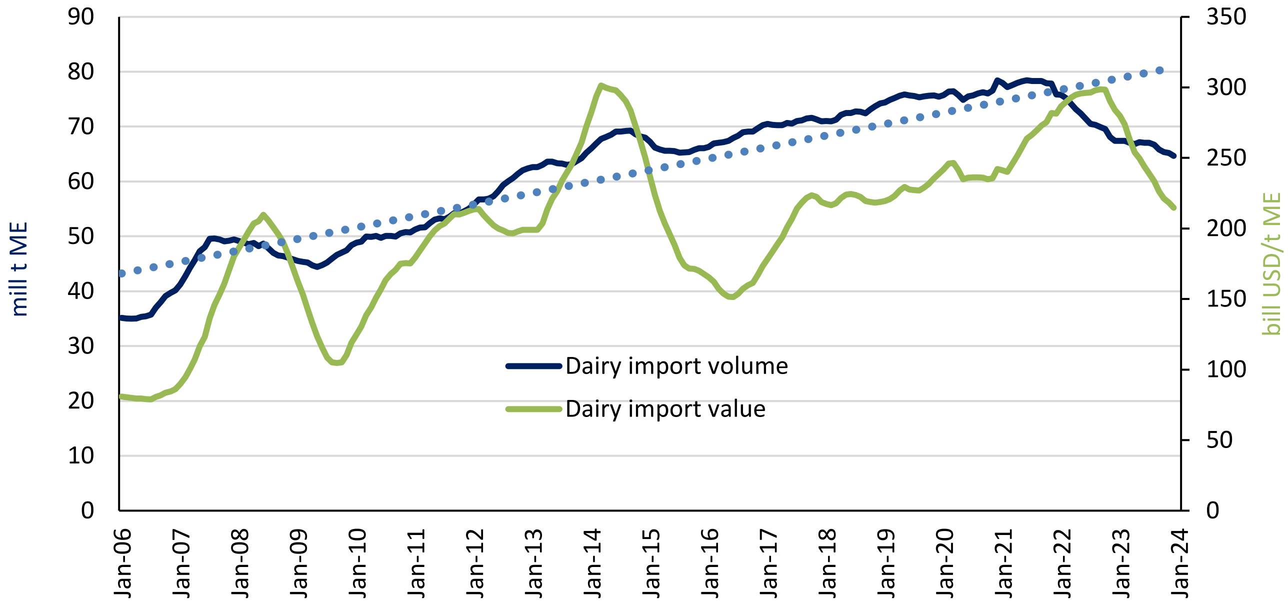

Figure 11: Global dairy imports (monthly)
Source: IFCN trade data source - GlobalTradeTracker (GTT) that provides monthly trade data for 26 dairy commodities at a level of 6-digit Harmonized System (HS) codes converted with their respective milk equivalents (ME) and summed up

Russia's aggression in Ukraine had severe repercussions throughout the global dairy supply chain, from farms to the final consumer, especially in the form of rising input and energy costs, as well as food inflation (Benton et al., 2022; Grant et al., 2023; World Bank, 2022). It had a spillover impact on feed costs, feed availability, and ultimately on dairy commodity prices and farmgate milk prices (Rabobank, 2022). Lower consumer demand has also reduced imports of poorer countries, such as Nigeria and Vietnam. The global trade contraction also resulted from lower availabilities and thus exports from a few leading exporters, including New Zealand and the European Union. In 2023, as expected (FAO, 2023a; FAO, 2023b), the global dairy trade continued to contract, albeit less steeply than in 2022. This further contraction was due to declines in imports by China, the Philippines, Indonesia, and Malaysia. The current global dairy trade map highlights a few notable trade flows: New Zealand's exports to China, United States shipments to Mexico, EU exports to the UK, and milk shipments from Belarus to Russia (Rabobank, 2023). Any subtle shifts in the volume of these trade flows can profoundly affect the fundamentals of the global dairy market.

China's impact on the world dairy trade is substantial. Its accession to the World Trade Organisation in 2001 lifted trade barriers and opened the Chinese market for exports. The Chinese milk scandal in 2008, when milk and infant formula were adulterated with the chemical melamine, led to Chinese consumers losing trust in local brands, resulting in a growing milk deficit (Li et al., 2021). The high demand from China was one of the reasons for the global milk price increase observed in 2008 and 2009. Between 2008 and 2023, Chinese imports of dairy products increased from 0.3 million tons ME to 111.4 million tons ME, making China the world's largest dairy importer. This strong growth resulted from a steady increase in Chinese demand for dairy products, which was driven by per capita consumption growth. In order to improve China's self-sufficiency in dairy products, the Chinese government has been strongly stimulating national supply growth through dairy programmes and large-scale dairy farm investments, especially after the COVID-19 pandemic. This resulted in annual milk output expansion, with much of the increased production originating from modernised large farms. In 2022, lower food service activities resulting from the Zero COVID-19 policy and rising domestic milk production led to a contraction in Chinese dairy imports, resulting in a significant impact on international trade. In 2023, contrary to global markets' expectations for a rebalancing of Chinese dairy imports following the lifting of COVID-related market restrictions, Chinese dairy imports did not increase in the second consecutive year. Continued domestic milk production growth and ample domestic stocks in China amid less-than anticipated demand from the hotel, restaurant, and institution sector have reduced dairy import requirements (FAO, 2024).

4 The IFCN Dairy Outlook 2030–2040–2050

The IFCN long-term dairy outlook presented in Table 5 aims to provide all stakeholders and political institutions within the dairy value chain with a clearer understanding of possible future developments in the dairy sector. Given the rapid changes in the dairy business, this outlook can serve as a guide for strategic planning and for identifying global potentials in dairy production.

There are two key drivers for the future development of the dairy market. First, demand will increase due to strong economic growth and population increases in major dairy-importing countries. Second, the global supply will be constrained by environmental regulations in major dairy exporters, such as New Zealand and the EU, as well as by weather conditions. Other factors that are expected to play a substantial role in the future development of the dairy market are the difficulties in attracting labour to dairy farms and the challenges of recruiting skilled individuals for increasingly digitalised farm operations. Other megatrends considered in the outlook with an influence on future global dairy sector developments are as follows:

i) The cost of milk production will increase due to higher prices for essential resources, such as feed, energy, labour, and fertilisers.
ii) Farm consolidation is continuing.
iii) Farm productivity and efficiency will continue to increase.
iv) Plant-based alternatives to milk will gain traction.
v) The balance between rising labour costs and its shortage and the adoption of automation technology will offer promising solutions to improve efficiency, reduce costs, and enhance sustainability.

Table 5: Dairy world in 2020, 2030, 2040, and 2050

World	Unit	2020	2030	2040	2050	Change in 2050 vs. 2020		
						Absolute	%	CAGR % year
Milk supply and demand								
Milk production	mill t SCM	935	1 106	1 231	1 331	396	42%	1.2%
Milk demand	mill t SCM	932	1 117	1 261	1 388	456	49%	1.3%
World trade								
Excl. EU-28 intra-state trade	mill t SCM	67	65	70	78	11	16%	0.5%
Supply drivers								
Number of milk animals	mill head	367	371	334	292	-77	-21%	-0.8%
Average milk yield	t/milk animal/year	2.4	2.9	3.5	4.4	2	80%	2.0%
Farm number	mill	115	100	78	46	-68	-59%	-3.0%
Average farm size	head/farm	3.2	3.7	4.3	6.3	3	95%	2.3%
Demand drivers								
Population	bill	7.7	8.5	9.1	9.6	3	24%	0.7%
Dairy consumption per capita	kg ME/capita/year	120	132	138	144	24	20%	0.6%

Source: IFCN Outlook developed in March 2024; Explanations: Scenario assumptions: GDP growth 3.1–3.4%; exchange rate of 1.1 USD/EUR; world oil price of 85 - 90 USD/barrel. Abbreviation: compound annual growth rate (CAGR), milk equivalents (ME), solid-corrected milk (SCM)

The expected regional milk surplus and deficit in 2030 are depicted in the map available in Appendix M. Caution should be exercised when interpreting the results of this outlook, as only 0.2% of all farms around the world have over 100 cows, and these farms all together produce 45% of the global milk. Most of these farms are located in Europe. Should these farms reduce their production due to environmental regulations, this would have a significant impact on the supply and, in the end, the world milk price. In other regions, small-scale farmers may struggle to grow rapidly, especially in developing countries, due to limited access to capital. Promising regions such as Latin America, which show mostly family farms, are not expected to record a fast consolidation; however, Latin America is the only world region with a decreasing number of cows per farm. Oceania and the United States, with big business farms, are also limited in terms of milk production growth potential due to policies aimed at reducing emissions and climatic conditions. Consequently, supply in major export countries, such as Oceania and Western Europe, is forecasted to decrease. Latin America and Eastern Europe may compensate—at least partly—for this decline in production, but these two regions also face various problems, such as political instability and climate change. The IFCN, therefore, expects the global demand for dairy products to increase faster than the supply. The future unsatisfied demand in 2030 is estimated at 11 million tons SCM and is expected to increase more until 2050. Imbalance in the dairy trade is likely to increase prices, which may, in turn, negatively impact demand. This expected paradigm shift in the dairy market may have policy implications in terms of food security and affordability not only in emerging markets but also in Europe and Oceania.

5 Conclusion

Global dairy farming sector is very heterogeneous, especially in terms of farm size and type. It is therefore facing different challenges under different contexts. This huge heterogeneity must be considered when analysing the sector's trends. The global dairy market has experienced a paradigm shift in the last decade, moving from a supply-driven market to a demand-driven market as a consequence of world population growth and an increase in per capita consumption in developing countries. This shift has led to a strong increase in farm-gate milk prices and is expected to remain the main driver of the future development of the dairy market, with demand expected to increase more strongly than supply. Besides this paradigm shift, the global dairy market is—on a more short-term basis—increasingly affected by geopolitical conflicts and extreme weather conditions resulting from climate change. This results in higher market volatility. These developments suggest that better profitability of dairy farming can be expected in the future. However, farmers will likely have to face higher volatility and will therefore have to develop strategies for coping with this volatility and related business risk. Even if the future of dairy farming seems to look much more promising than it looked 20 years ago, one should be aware that there are still many uncertainties in terms of the future development of the market. For instance, the extent to which plant-based alternatives to dairy products will develop in the long run or their impacts on the dairy market remain unclear. Furthermore, the extent of the negative consequences of climate change on dairy farming and especially fodder production may be much stronger than expected, which would have a negative impact on supply and, in the end, affect dairy farming profitability both in terms of returns (higher milk prices) and costs (higher costs). Finally, dairy farming will have to contribute to reducing the negative environmental impact of agriculture. Although, as currently observed at the EU level, environmental political ambitions may be watered down in the short run, environmental sustainability will remain a key issue in the dairy business in the long run. Environmental impact reduction is especially a challenge for dairy production systems that rely heavily on concentrated feed. Feed production on arable land is indeed much less favourable in terms of environmental efficiency than if this arable land were used directly for human food. The cow is a ruminant and therefore is able to convert cellulose, which cannot be digested by humans, into edible human food. It is, therefore, predestined to produce milk on land that can only be used for grassland production. In this respect, grassland-based milk production systems could have a promising future, as they compete less with arable land for direct human consumption and are also expected to be more resilient to market price volatility. However, these systems may be more vulnerable to climate change due to their strong dependence on roughage production. Thus, the extent to which they are affected by climate change determines their long-term viability.

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10 Appendix A: About the International Farm Comparison Network (IFCN)

Vision, Mission, and Identity of IFCN

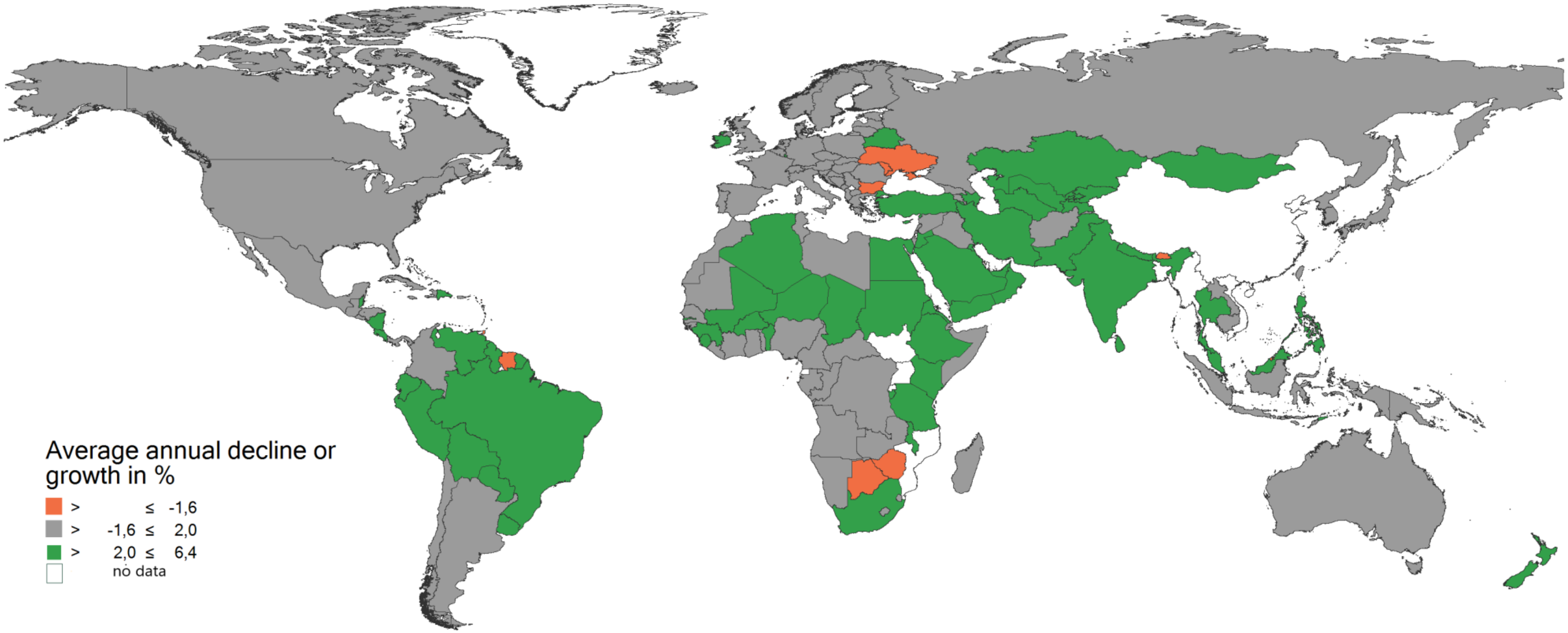
IFCN Vision	IFCN Mission
IFCN is a leading, global knowledge organization in milk production, milk prices and related dairy economic topics.	IFCN helps people in the dairy world with dairy data, knowledge and inspiration to make better decisions.
IFCN identity, competence and research activities	
Founded in 2000, IFCN is a global scientific network that links dairy researchers from over 100 countries. IFCN has a Dairy Research Centre with approximately 10 researchers coordinating the network process and running dairy research activities (based in Kiel, Germany). IFCN provides globally comparable dairy economic data and forecasts. Cooperation with IFCN offers access to methods, models, and data.	The research activities include: - Creating a harmonised database of typical farms and the dairy sector - Global benchmarking of dairy farming systems - Monitoring prices and farm structure - Analysing dairy farms and dairy sector developments using IFCN methods - Conducting policy impact analysis - Exchanging ideas on current dairy issues and research projects - Improving IFCN methods continuously - Publish results in the Dairy Report

The major inputs and outputs of IFCN participation.

Input	Output	Use of outputs
Country Dairy Sector Data	Global holistic overview of the dairy world A comparable database for analysis Annual IFCN Dairy Report with more than 200 countries included Own country's IFCN Long-term Dairy Outlook	Analysing dairy markets in scientific articles (e.g. Jan and Gazzarin, 2019; Gazzarin, 2007; Gazzarin, 2005; Kozak, 2009; Kozak et al., 2022), presentations, external projects within and outside own organization Using IFCN tools to convey knowledge to dairy stakeholders
Typical dairy farm data (2-4 farms per country)	Complete IFCN farm-level results database with time series for 52 countries Using rights for Model TIPI-CAL[7]	Analysing farm competitiveness International benchmarking of typical farm Gaining knowledge about different dairy farming systems
Annual IFCN Conference participation	IFCN results presentation Methods and models discussion Networking with dairy researchers from different countries IFCN Dairy Newsletter IFCN press releases	Complementing with data for own country and present Using data and methods to define the right dairy strategy Sharing with dairy-related colleagues and stakeholders for have an overview of the dairy world Promoting and strengthening contacts Using insights for developing news articles, etc.
Monthly IFCN Researchers Meeting	Updated situation in the world dairy market Latest news from IFCN Network	Comparing a country's profile to global trends monthly and predict directions of national development Obtaining the latest information from other countries first hand

[7] The TIPI-CAL Model (TIPICAL=Technology Impact and Policy Impact Calculations) is an analytical tool for production, economic and environmental aspects of dairy farms. It was developed by Torsten Hemme (Hemme, 1999). The model allows to compare the data of all typical farms of the countries represented in the IFCN.

11 Appendix B: Annual change in milk production worldwide 2000–2023



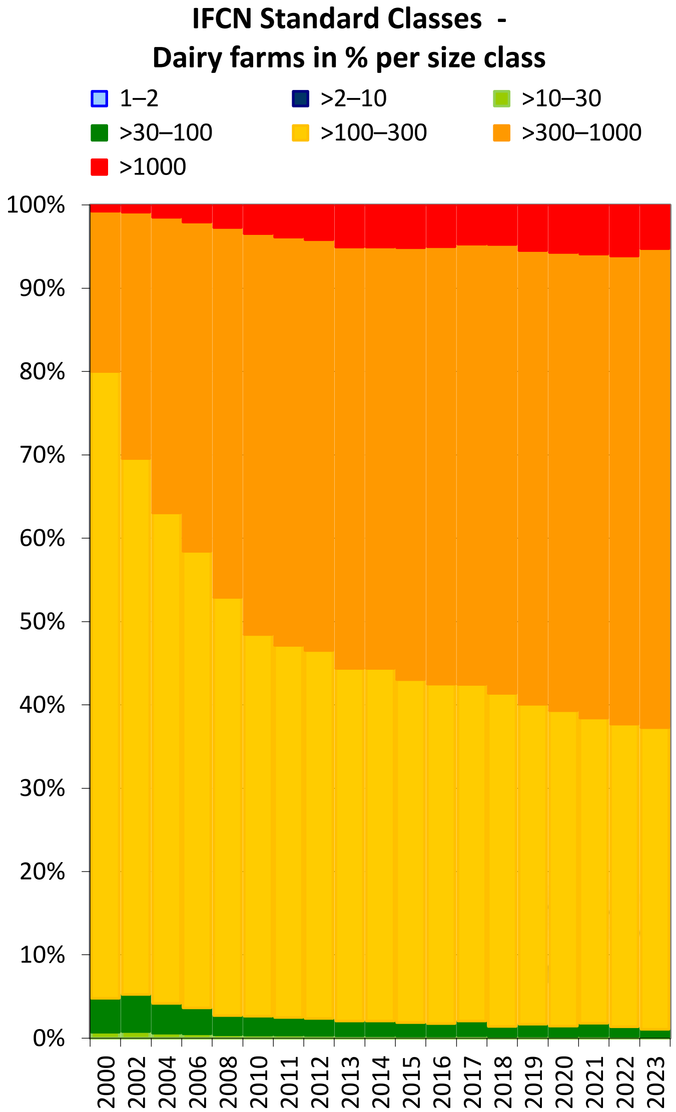
Source: IFCN standardised database

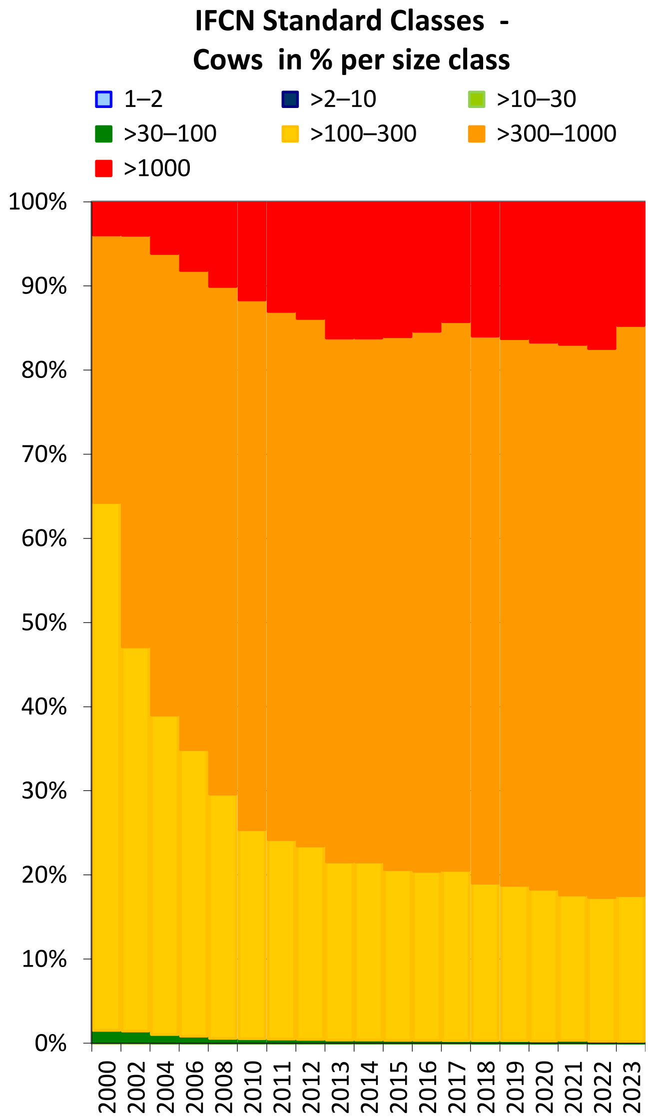
12 Appendix C: Structural changes in selected countries

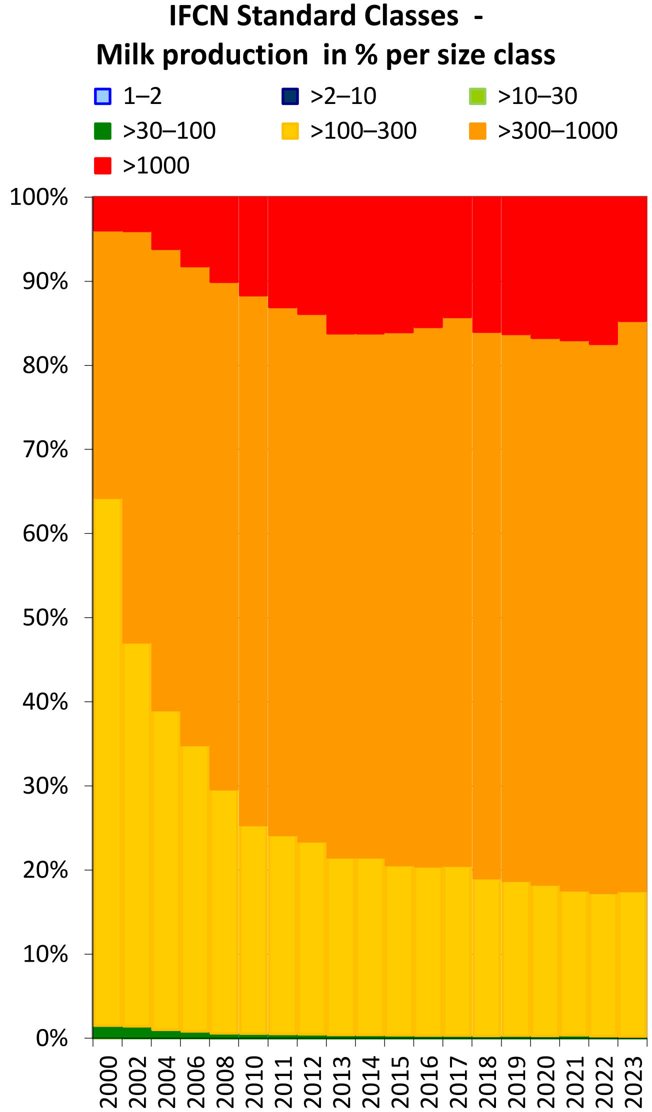
Country	No. of dairy farms (×1 000)			Average farm size, cows/farm		
	2000	2013	2023	2000	2013	2023
European Union	3 937	1 540	829	7.0	14.9	26.0
Argentina	16.5	11.9	10.2	130.3	151.3	155.8
Australia	12.9	6.4	4.2	168.4	263.8	305.1
Austria	67.0	35.1	24.6	9.3	15.0	21.4
Bangladesh	1 315	1 393	1 773	3.2	3.4	3.2
Belarus	577.2	107.0	29.1	3.2	14.3	49.6
Belgium	18.2	10.5	8.0	32.6	46.6	67.9
Brazil	1 605	1 231	1 110	11.1	18.6	14.1
Bulgaria	200.3	61.0	12.4	1.6	5.1	17.8
Canada	19.4	12.3	9.4	56.2	77.8	102.7
Chile	40.3	14.7	9.3	16.1	37.5	42.7
China	404	1 992	257.6	6.5	3.0	24.2
Croatia	102.8	30.2	10.4	2.6	5.6	8.7
Czech Republic	2.28	2.03	1.33	226.1	184.7	268.5
Denmark	10.5	3.7	2.3	60.6	158.2	241.0
Egypt	725	775	395	4.0	5.4	11.7
Ethiopia	1 597	2 486	3 000	6.5	4.3	5.2
Finland	23.9	9.6	4.7	15.2	29.4	52.0
France	120.0	66.0	42.6	34.6	56.0	74.4
Germany	138.5	79.5	50.6	33.0	53.7	73.4
India	55 911	77 710	66 619	1.9	1.6	2.1
Ireland	25.1	15.6	15.3	46.9	74.4	107.5
Israel	1.32	0.94	0.63	86.0	132.7	217.0
Italy	81.6	42.0	24.9	26.6	38.1	58.4
Japan	33.6	19.4	12.6	34.2	47.6	66.4
Kenya	627	1 688	2 100	5.3	3.0	2.4
Luxembourg	1.16	0.73	0.57	41.9	63.3	97.3
Mexico	126.3	134.7	88.3	16.4	17.9	30.4
Nepal	3 153	3 833	3 860	0.57	0.63	0.63
The Netherlands	31.5	18.7	14.3	48.6	83.2	110.4
New Zealand	13.9	11.9	10.6	235.9	402.2	441.0
Pakistan	10 119	7 184	6 713	1.5	3.2	3.5
Poland	1 281	341.1	166.1	2.4	6.7	12.5
Saudi Arabia	0.03	0.03	0.03	2 107	5 749	8 152
South Africa	4.90	2.00	1.04	111.2	311.0	601.0
Spain	56.4	19.4	10.3	21.0	42.3	76.1
Sweden	12.2	4.7	2.7	35.1	73.7	111.2
Switzerland	33.9	23.5	17.2	19.8	25.1	30.6
Turkey	2 147	1 250	964	2.5	4.5	6.5
Ukraine*	14.0	3.2	1.4	132.0	176.6	265
United Kingdom	28.4	14.3	10.8	82.2	124.8	169.6
The United States	82.9	47.0	26.3	110.9	196.4	355.9
Uzbekistan	1 079	2 119	2 298	2.2	1.9	2.2
World	***99.6****	***119.9****	***108.7****	***3.0***	***2.9***	***3.5***

*Source: IFCN standardized database; *Ukraine – formal sector (excluding households), **in million*

13 Appendix D: Farm structure in New Zealand

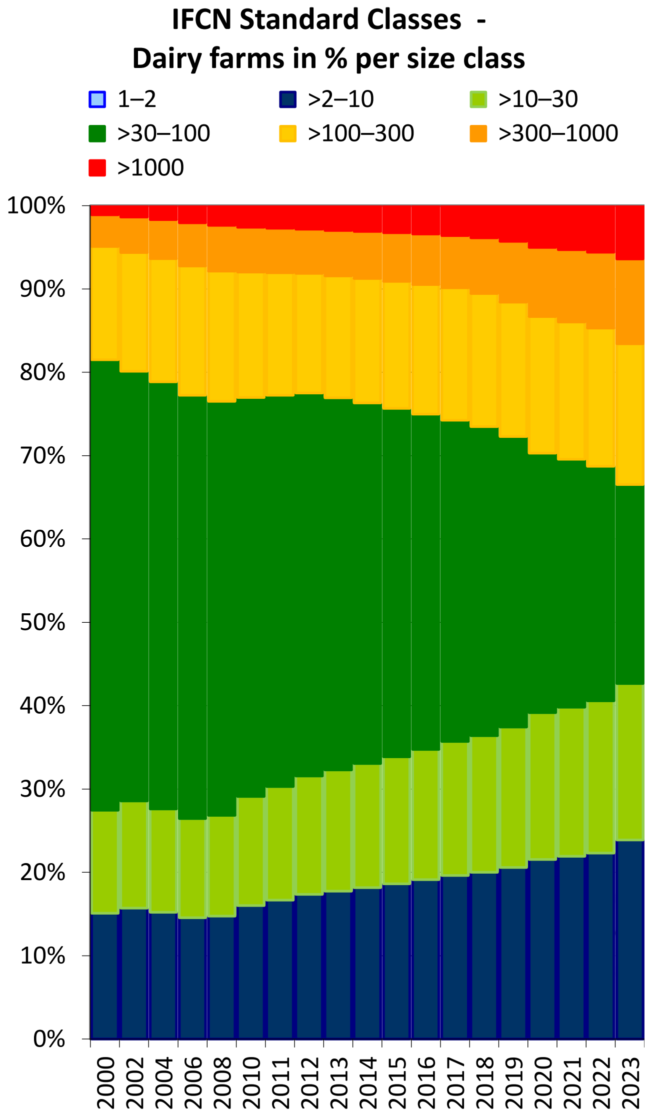


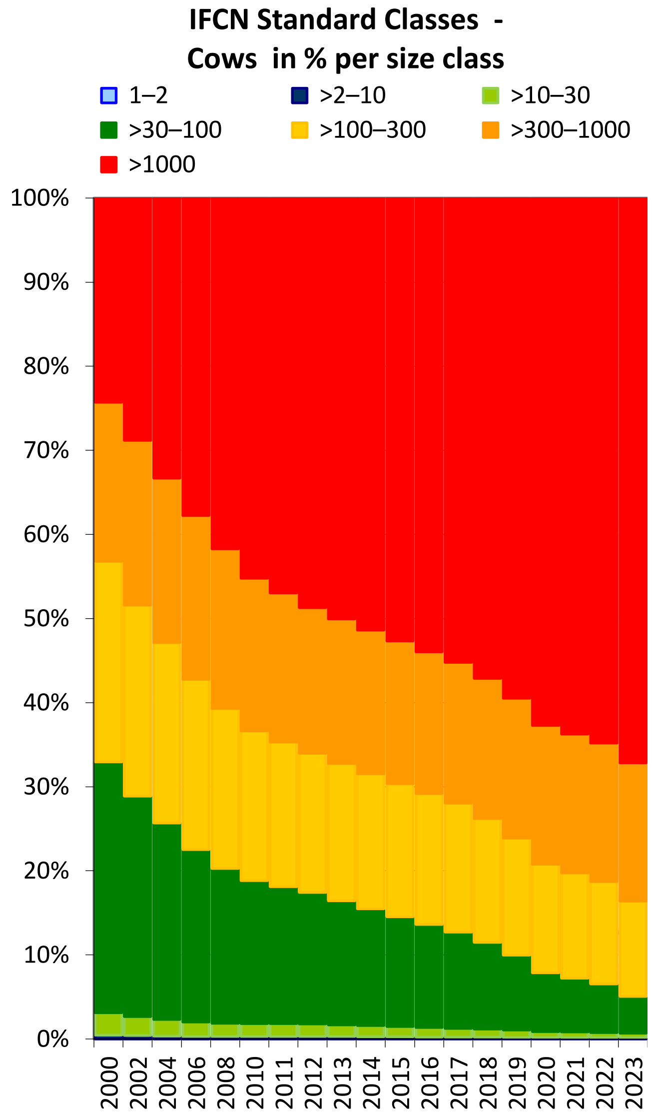


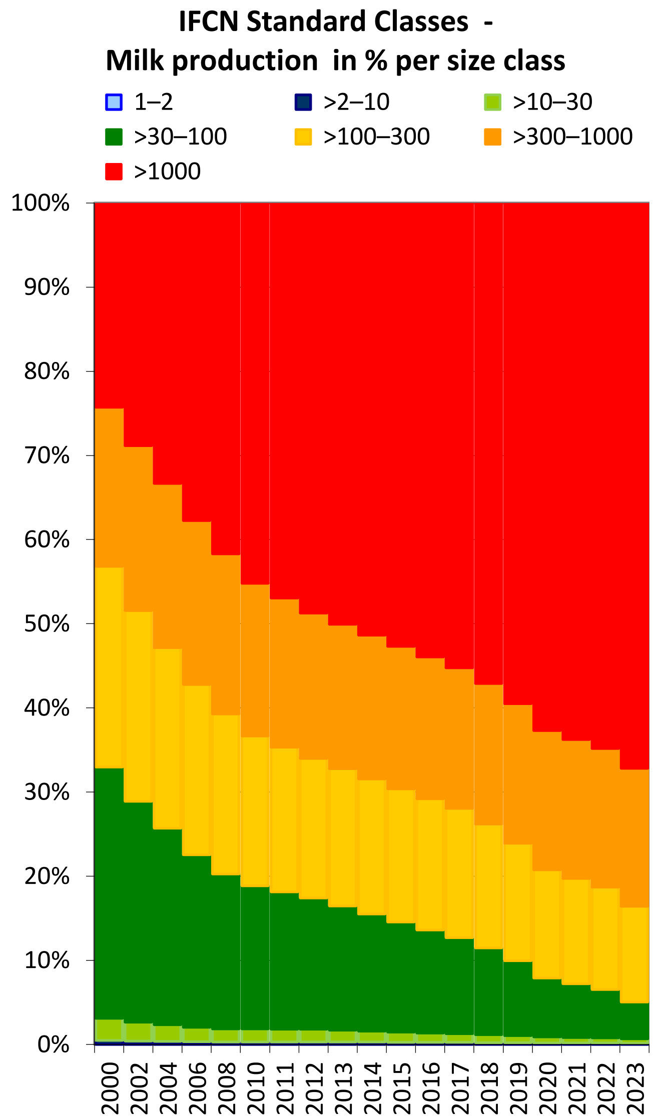


Source: IFCN Farm Structure Data represented according to the IFCN standard classes

14 Appendix E: Farm structure in the United States

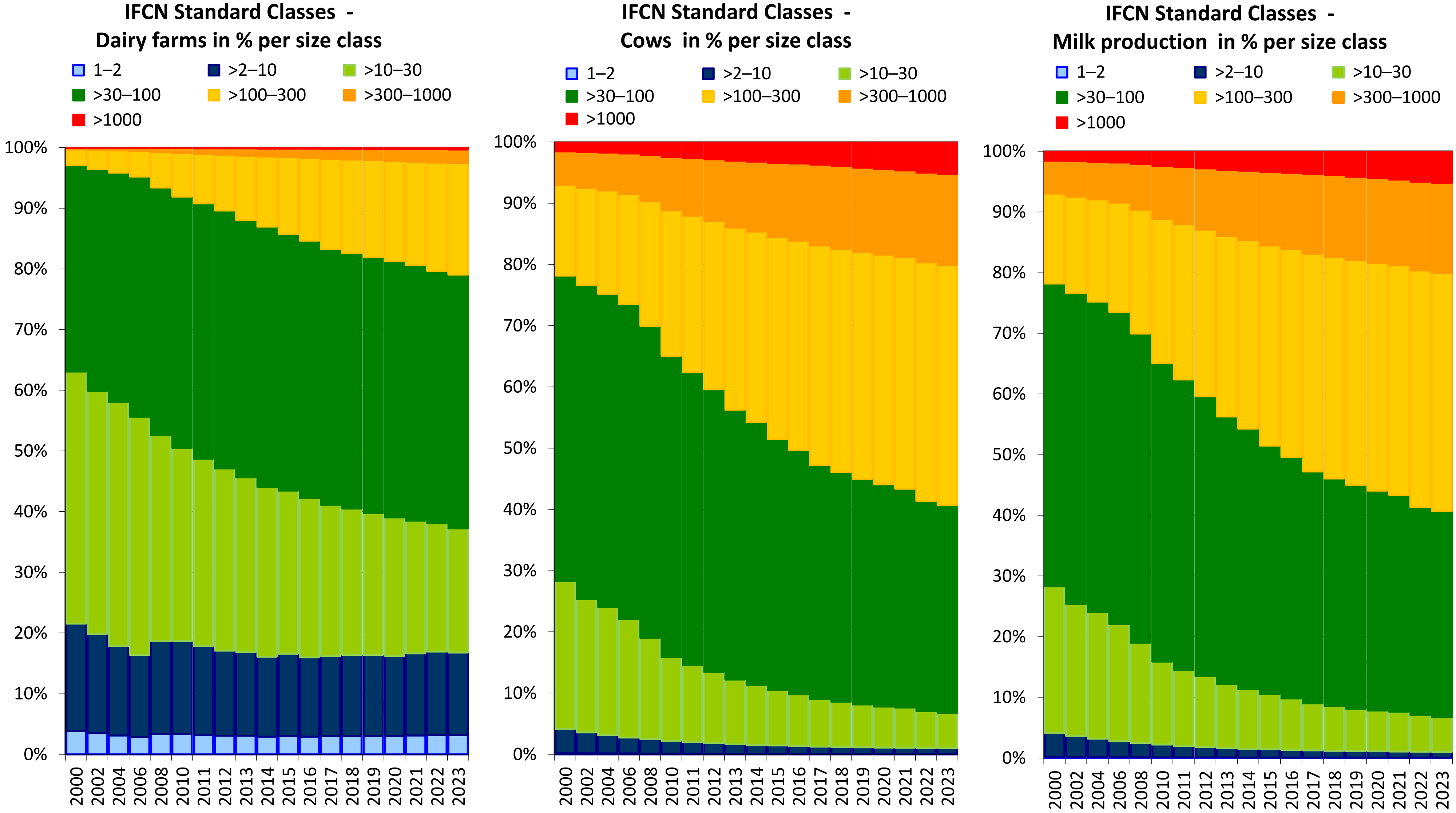






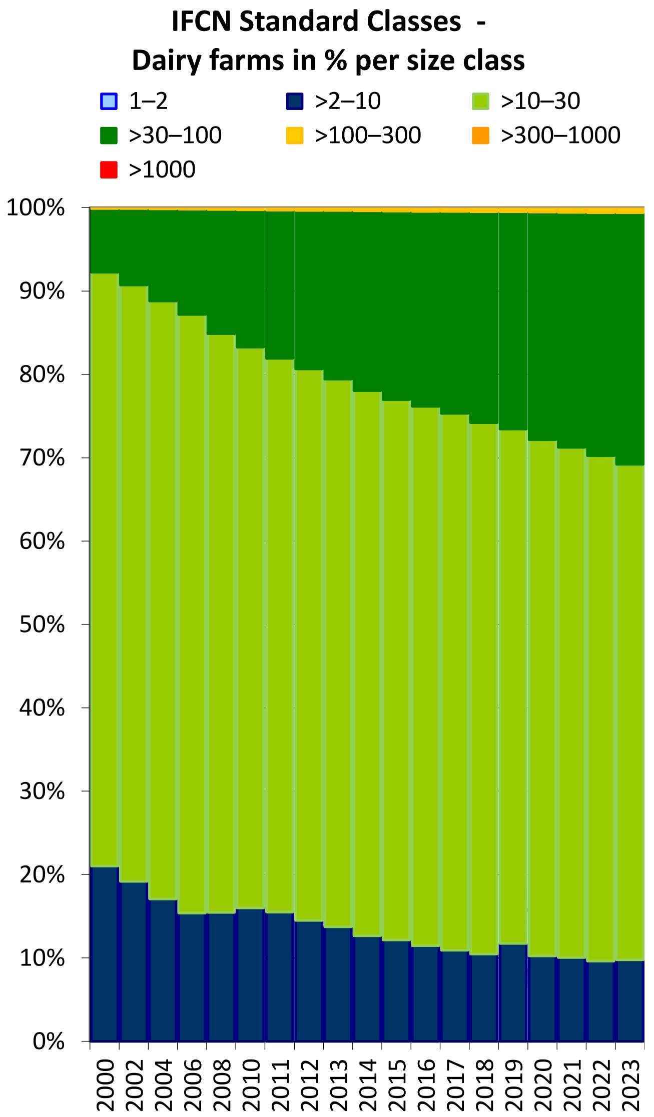
Source: IFCN Farm Structure Data represented according to the IFCN standard classes

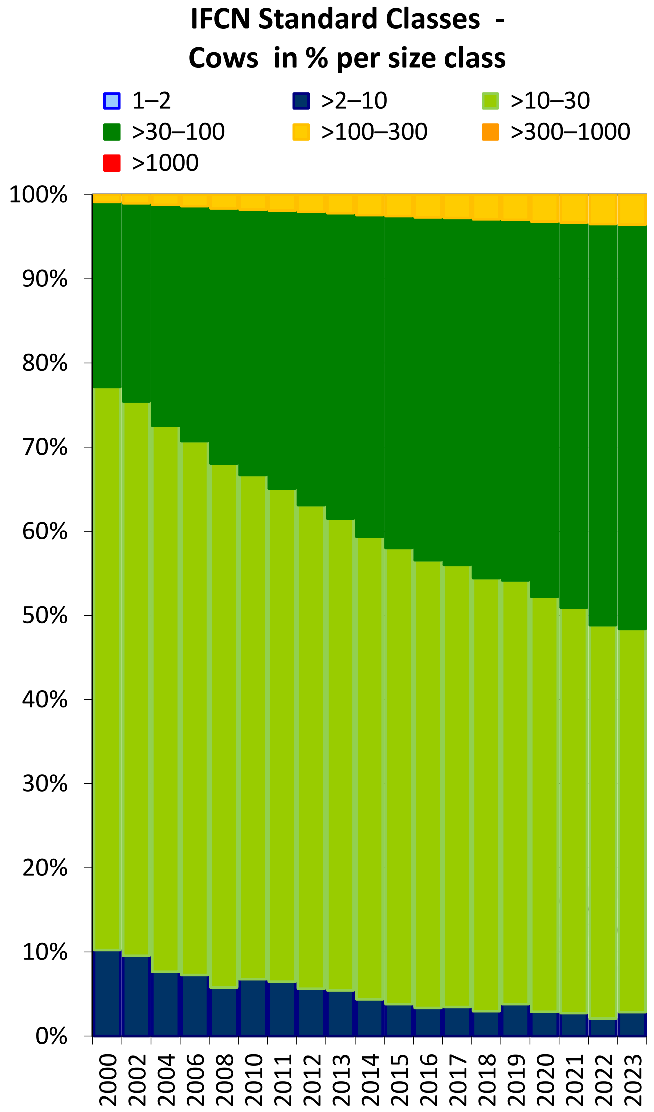
15 Appendix F: Farm structure in Germany

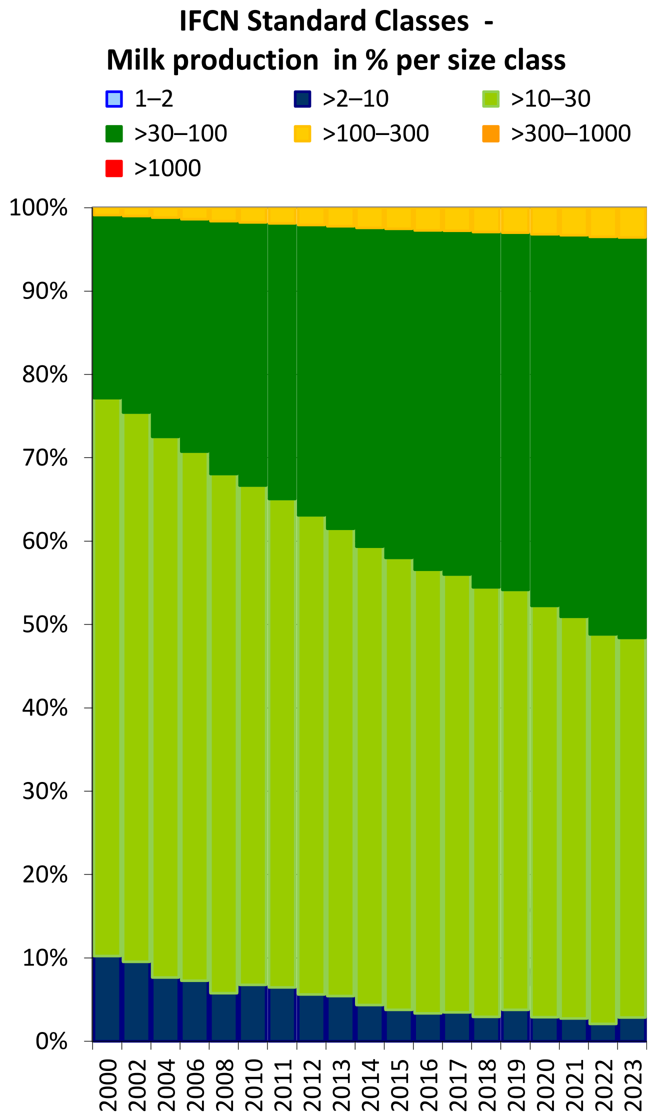


Source: IFCN Farm Structure Data represented according to the IFCN standard classes

16 Appendix G: Farm structure in Switzerland

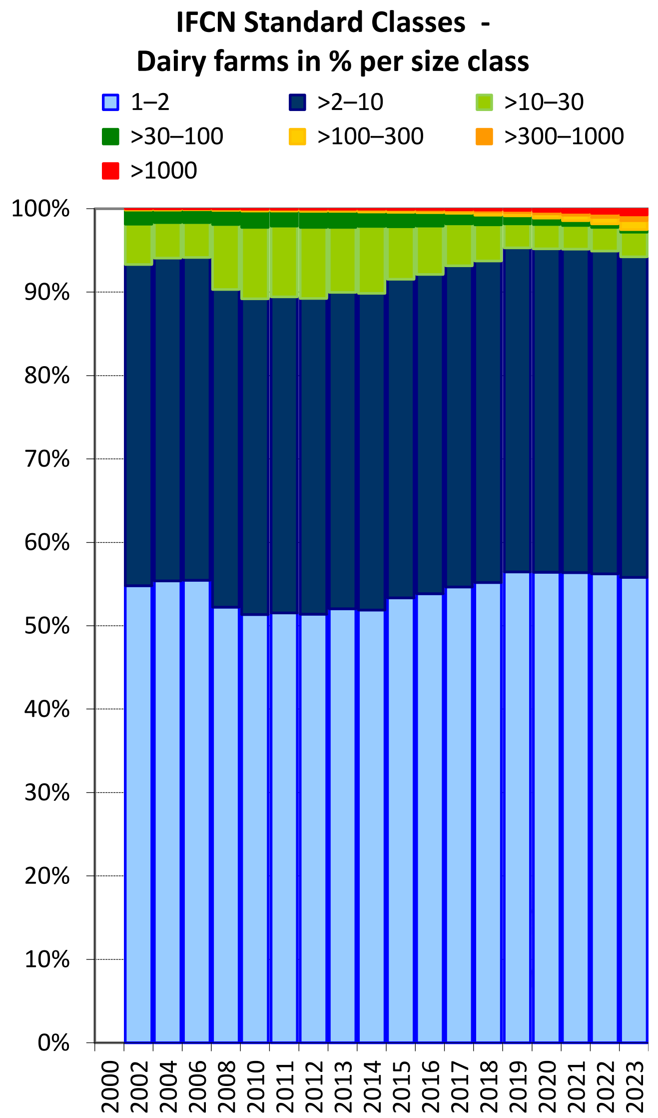


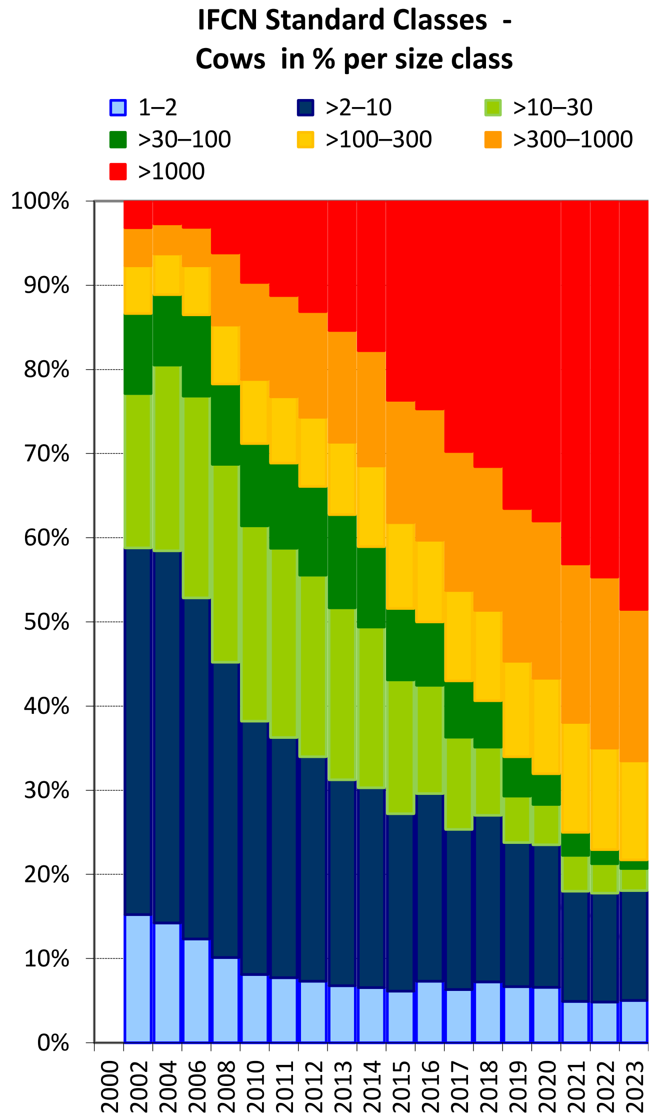


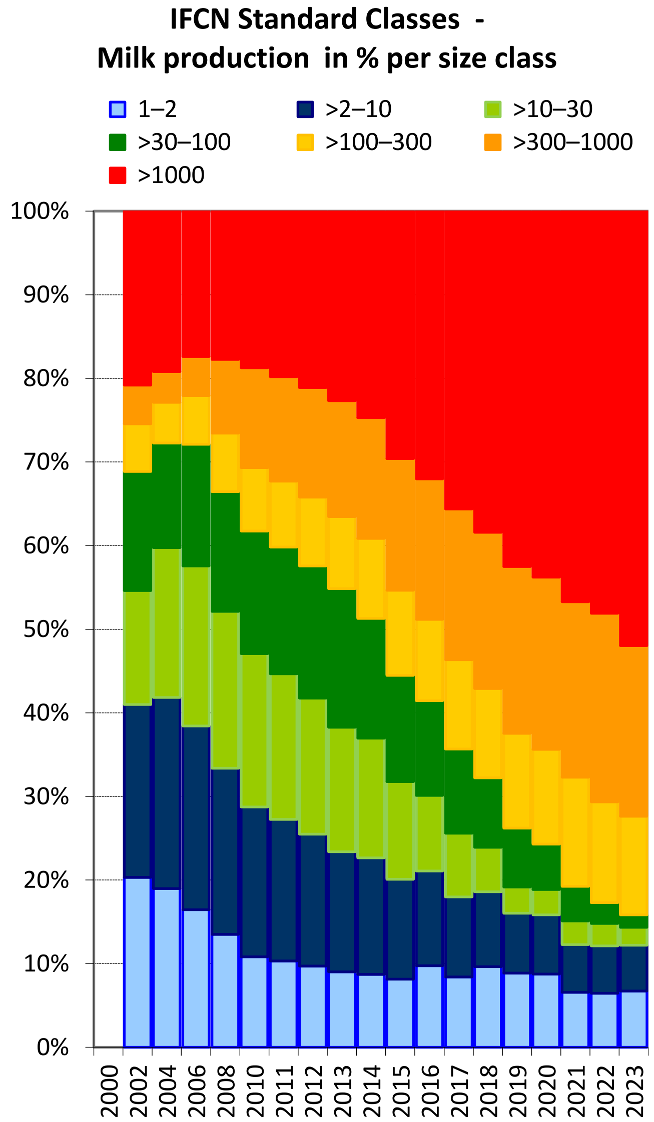


Source: IFCN Farm Structure Data represented according to the IFCN standard classes

17 Appendix H: Farm structure in China

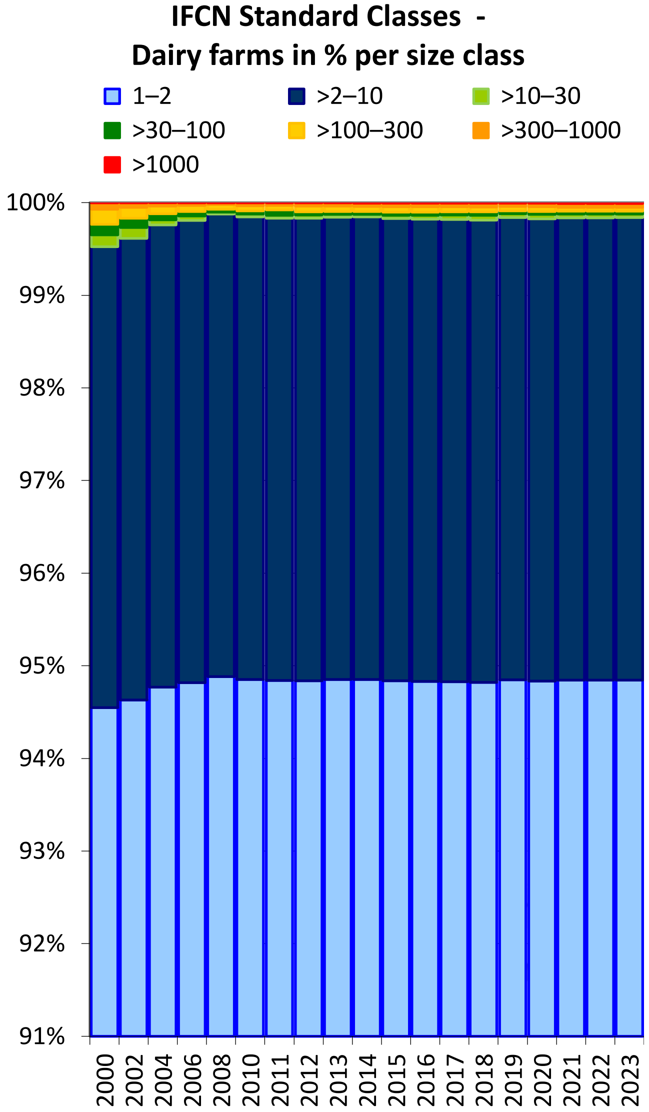


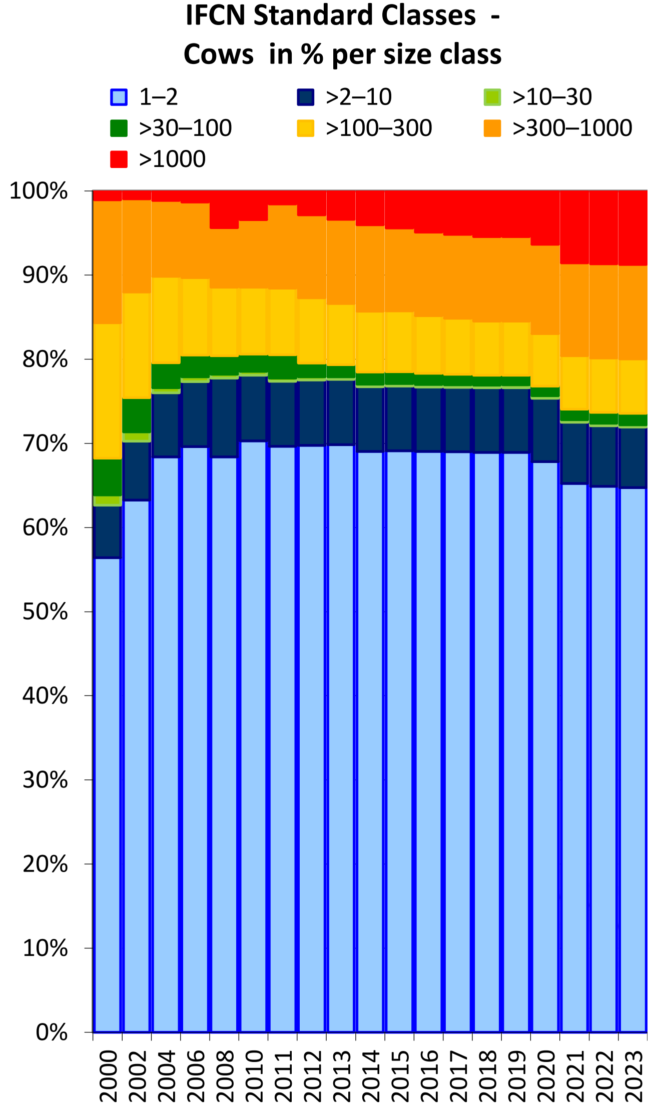


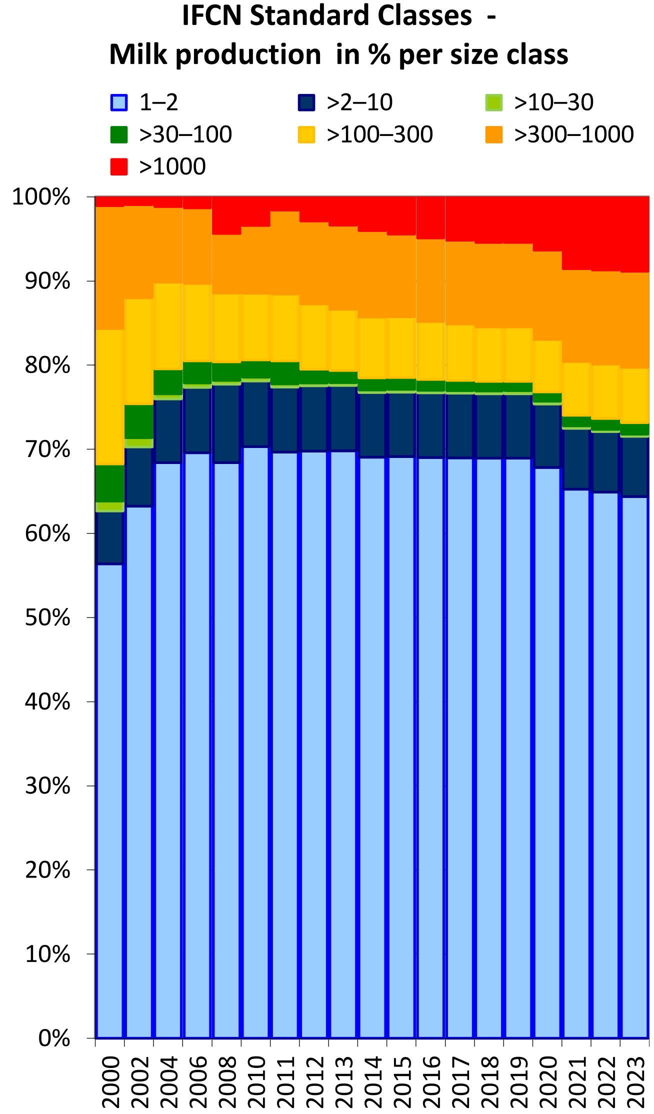


Source: IFCN Farm Structure Data represented according to the IFCN standard classes; 2000 – data is not available.

18 Appendix I: Farm structure in Ukraine

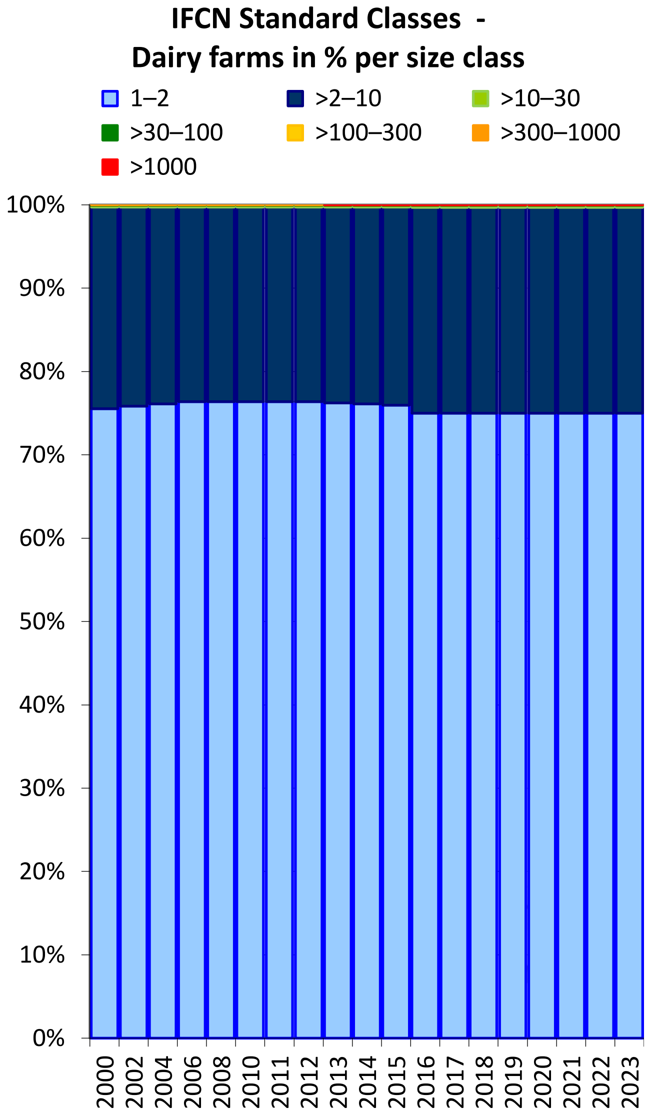


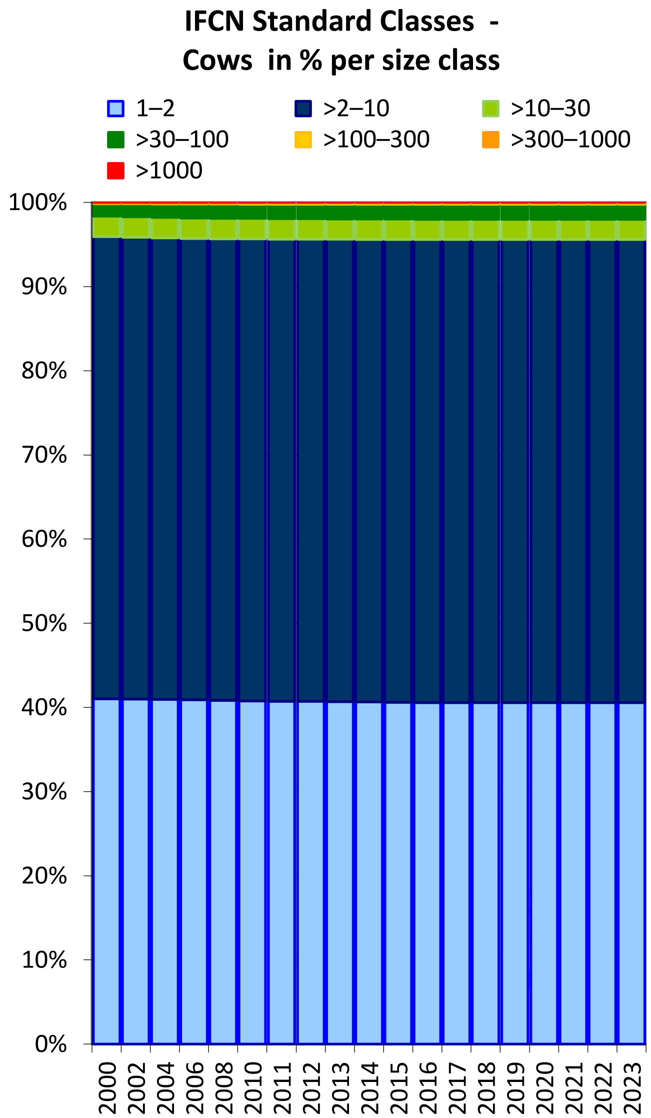


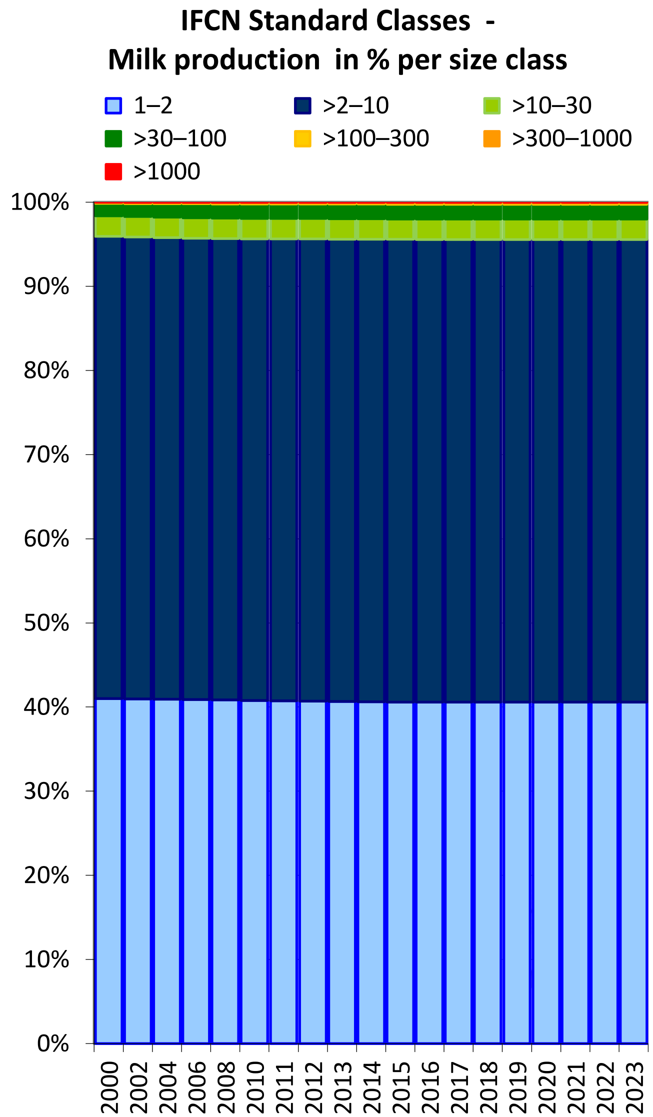


Source: IFCN Farm Structure Data represented according to the IFCN standard classes

19 Appendix J: Farm structure in India

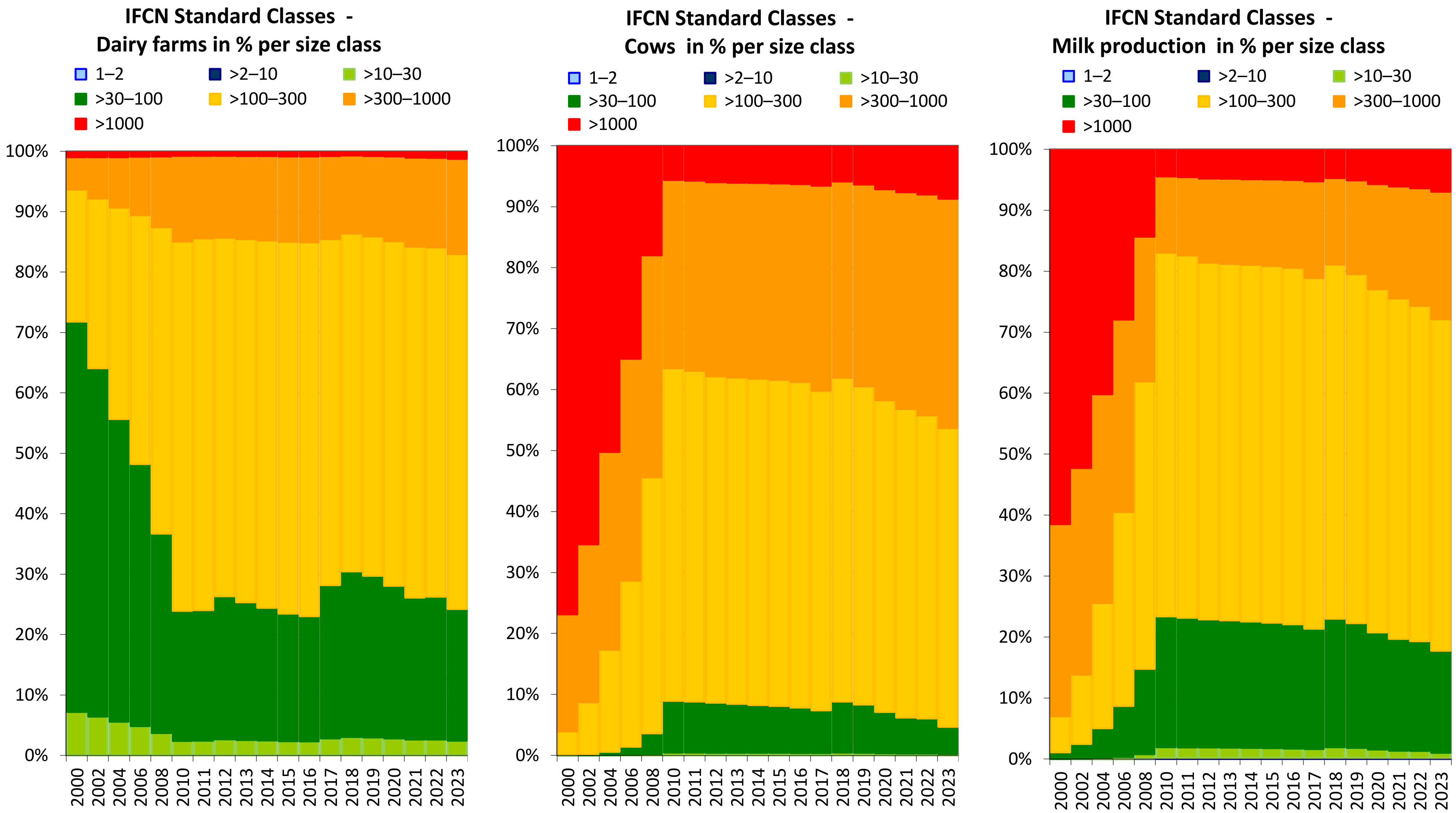






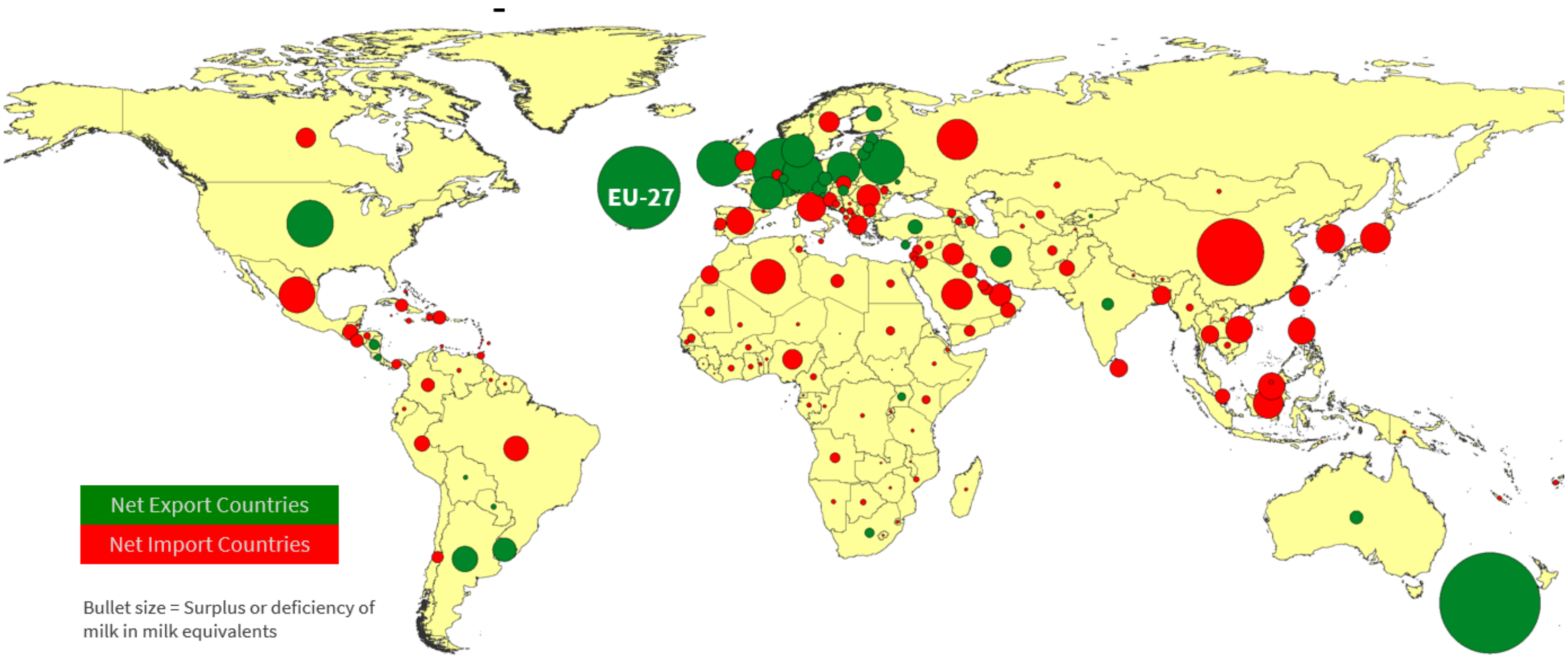
Source: IFCN Farm Structure Data represented according to the IFCN standard classes

20 Appendix K: Farm structure in Argentina



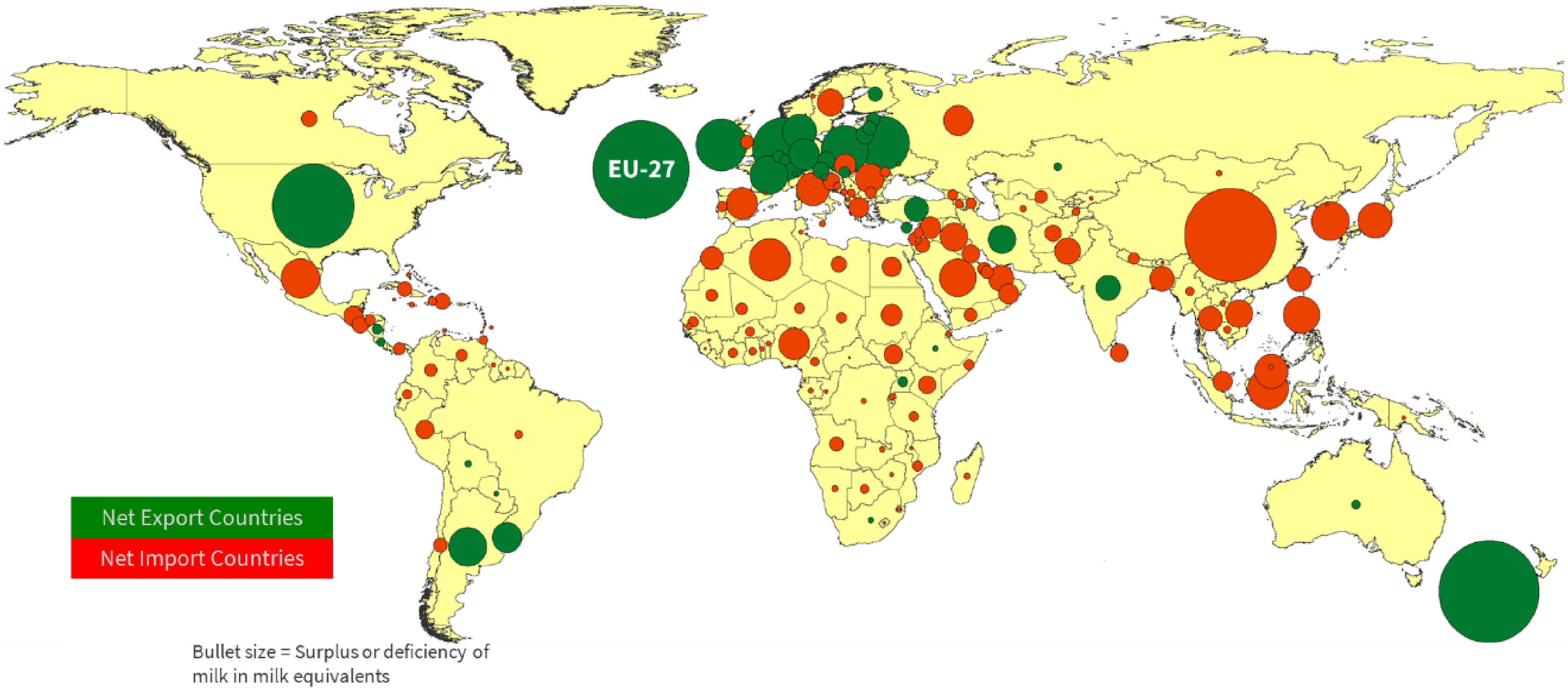
Source: IFCN Farm Structure Data represented according to the IFCN standard classes

21 Appendix L: Milk surplus and deficit in 2023



Source: IFCN calculations based on national statistics, GlobalTradeTracker (GTT), FAO, and IFCN estimations for some countries; calculation of milk surplus or deficit: milk production minus milk demand.

22 Appendix M: Milk surplus and deficit in 2030



Source: IFCN Annual Sector Database with Long-term Dairy Outlook