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Progress towards sustainable agriculture

Drivers of change

FAO AGRICULTURAL DEVELOPMENT ECONOMICS TECHNICAL STUDY

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Preface

To nourish and sustain current and future generations, there is an urgent need for a development path towards sustainable agriculture. This pathway must not only ensure increasing output. It must also make more efficient use of increasingly scarce global resources, be resilient to and help mitigate climate change, and improve human well-being.

Progress towards sustainable agriculture is essential for achieving the Sustainable Development Goals (SDGs) that underpin the 2030 Agenda for Sustainable Development. Agriculture remains the main source of livelihood for the majority of the world's poor and hungry. Making agriculture more sustainable – productive, environmentally friendly, resilient and profitable – is fundamental to ending poverty and hunger (SDGs 1 and 2), and promoting decent work and economic growth (SDG 8). Moreover, given the current impact of agriculture on the degradation of environmental resources, a more sustainable agriculture is key to improving the availability of clean water (SDG 6), promoting sustainable consumption and production (SDG 12), and fighting land degradation and loss of biodiversity (SDG 15), among others.

The global vision for a sustainable agriculture that achieves these interrelated goals is articulated in SDG 2, which calls for the global community to "end hunger, achieve food security and improve nutrition, and promote sustainable agriculture". Under SDG 2 Target 4, the global community has set specific goals for achieving a more sustainable agriculture: "by 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality." The SDG indicator 2.4.1 seeks to measure progress towards Target 4 in terms of the "proportion of agricultural area under productive and sustainable agriculture." Productive and sustainable agriculture has been defined holistically through a global consultative process, leading to the approval of 11 sub-indicators that seek to capture the complexities of the economic, environmental and social dimensions of sustainable agriculture. Through this holistic approach, indicator 2.4.1 can be used by countries to monitor progress towards sustainable agriculture with just and socially equitable agricultural systems that conserve and regenerate natural resources, while providing farmers a decent standard of living and producing enough food to feed growing populations.

The Food and Agriculture Organization of the United Nations (FAO) is the custodian of SDG indicator 2.4.1, and works directly with its Member Countries to develop the complex data collection systems to monitor and report its sub-indicators, and to design development strategies to achieve a more sustainable agriculture. The 11 sub-indicators that comprise SDG indicator 2.4.1 require the development and implementation of farm surveys for effective data collection. FAO is currently working with its Member Countries to develop the required data collection systems, with results expected over the medium to long term.

While SDG indicator 2.4.1 progresses on the data front, the international community must continue advancing the global sustainable agriculture agenda. The Progress towards Sustainable Agriculture initiative (PROSA) is a framework that seeks to complement ongoing efforts on SDG indicator 2.4.1 and to support country-level assessments using data already available at national level. The PROSA indicators follow the SDG indicator 2.4.1 framework as closely as possible, to compare countries' progress across economic, environmental and social dimensions of sustainable agriculture using the breadth of data available at FAO and reported by Member Countries.

The work under PROSA has two main objectives. First, it aims at consolidating the current knowledge on the trends in the selected PROSA indicators of agricultural sustainability (Tubiello *et al.*, 2021). Second, PROSA examines in detail the key factors that are driving changes in the indicators that are the focus of this technical study. By doing so, it provides, for the first time, a detailed picture of where the global community stands with respect to its sustainable agriculture goals, as well as evidence-based insights into key actions required to transition towards a more sustainable agricultural development pathway. This transition will not be easy, and will require navigating complex trade-offs and building upon synergies across the economic, environmental and social dimensions of sustainable agriculture. This technical study aims at providing guidance to national and international decision makers to help chart appropriate sustainable development pathways.

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Acronyms

FAO	Food and Agriculture Organization of the United Nations
FDI	foreign direct investment
GDP	gross domestic product
GHG	greenhouse gas
GII	Gender Inequality Index
HLPE	High-Level Panel of Experts on Food Security and Nutrition
LASSO	Least Absolute Shrinkage and Selection Operator
NRA	Nominal Rate of Assistance
OECD	Organisation for Economic Cooperation and Development
PETT	Special Land Titling and Cadaster Project
PROSA	Progress towards Sustainable Agriculture
SDG	Sustainable Development Goal
UNDP	United Nations Development Programme

Executive summary

Sustainable Development Goal (SDG) 2 calls for global action to "end hunger, achieve food security and improved nutrition, and promote sustainable agriculture". **Meeting this challenge requires global partnerships to support more productive, nutritious and equitable food systems, while helping to conserve environmental resources and reduce the greenhouse gas (GHG) emissions responsible for global climate change.** The Food and Agriculture Organization of the United Nations (FAO) offers a global vision for a more sustainable agriculture that encompasses economic, social and environmental dimensions of food and agriculture systems.

This technical study examines the key factors driving changes in trends in the globally agreed upon indicators for sustainable agriculture and provides decision makers with insights into viable options for achieving this goal. To monitor the progress towards sustainable agriculture, the global community has recently established SDG target 2.4 and the associated indicator 2.4.1. **Indicator 2.4.1** measures the share of the land under sustainable agriculture. It is comprised of a set of sub-indicators associated with the economic, social and environmental dimensions of sustainability, and includes land productivity, farm profitability, socio-economic resilience, soil health, water use, fertilizer and pesticide risks, biodiversity, decent employment, land tenure and food security.

The study identifies five key groups of drivers that most influence these sub-indicators globally. The ways in which each driver affects the multiple dimensions of sustainability highlights the interconnections, synergies and trade-offs that must be managed in different global contexts to achieve agricultural sustainability. The analysis contained in this report can help decision makers operating in different country contexts to identify practical solutions to ensure that their interventions contribute positively to a more sustainable agriculture.

Key findings of factors driving changes in sustainable agriculture

- **Demographic dynamics.** Meeting the food needs of a growing and more affluent global population is putting pressure on farmers to produce more, through land expansion, intensification, or a combination of both. In many developing countries, growing rural populations are accelerating agricultural land expansion and soil degradation. A lack of jobs outside agriculture, particularly for youth, is increasing pressure on agricultural land, and is reinforcing land degradation and low land productivity. Integrating job creation and sustainable intensification strategies should be a key part of any approach to make agriculture and livelihoods more sustainable.
- **Farm size structure.** Larger and more mechanized farms are generally more profitable, due to key advantages in terms of economies of scale, returns to specialization, and a greater ability to take risks with new farm management tools and technologies compared to smaller farms. However, large and highly specialized farms must manage the long-term environmental and economic sustainability of their production systems. Support to more diversified large-scale farms through, for example, improved market linkages for cover crops can improve their long-term environmental and economic sustainability. Small, diversified farms can generate valuable environmental services and economic resilience; however, they are often challenged by low levels of profitability. Improving the economic sustainability of small farms requires enhancing their access to scale-appropriate mechanization, linking them to low-cost agricultural service providers and supporting inclusion of more profitable commodities in their diversified systems. This will require a mix of interventions including development of input and output markets, risk management tools and quality control schemes.

- **Inequality.** Agricultural sustainability requires a substantial reduction of income inequalities and the removal of the structural inequalities facing marginalized groups. Unequal distribution of wealth and resources hinders agricultural productivity and economic prosperity, and undermines progress towards sustainable agriculture. The key steps to reduce inequality in agriculture include strengthening land tenure rights and developing innovative strategies to improve access to credit and agricultural services for poor and marginalized farmers, including women farmers. Improving gender equity contributes to greater agricultural productivity and food security, particularly due to the large and growing contribution of women to the agricultural workforce.
- **Global integration.** The global integration of agriculture through foreign direct investment (FDI) and global trade creates opportunities to increase economic resilience in agricultural systems, through incentives for diversification and improved access to credit for agriculture. However, greater export orientation of the farming sector may elevate the risk of overusing pesticides, with implications for human health and the environment. An influx of FDI may also contribute to an increase in inequality if complementary policies to ensure that local farmers and firms participate on equal footing are not in place. Reaping the benefits from global integration requires following the *Principles for Responsible Investment in Agriculture and Food Systems* (CFS, 2014).
- **Government support.** Governments support agriculture to achieve a diverse set of policy objectives across countries. The type of support provided and the way it is implemented may have important effects on sustainability outcomes. Input subsidies may be an important policy instrument to stabilize agricultural producers' incomes in the short term; however, they have limited effects on agricultural productivity in the longer term. They tend to absorb substantial amounts of public resources, while having weak income transfer efficiency due to poor beneficiary targeting. Output support can have a more positive effect on sustainable agriculture, by supporting markets for a diverse range of agricultural products. Still, they also have weak income transfer efficiency and may require substantial public expenditures. Alternative, less distortive policy measures yield higher returns in terms of agricultural productivity and farmer welfare than support to input use or commodity outputs. These measures include direct cash transfers to poor households and investments in public goods, such as research, knowledge transfer and infrastructure.

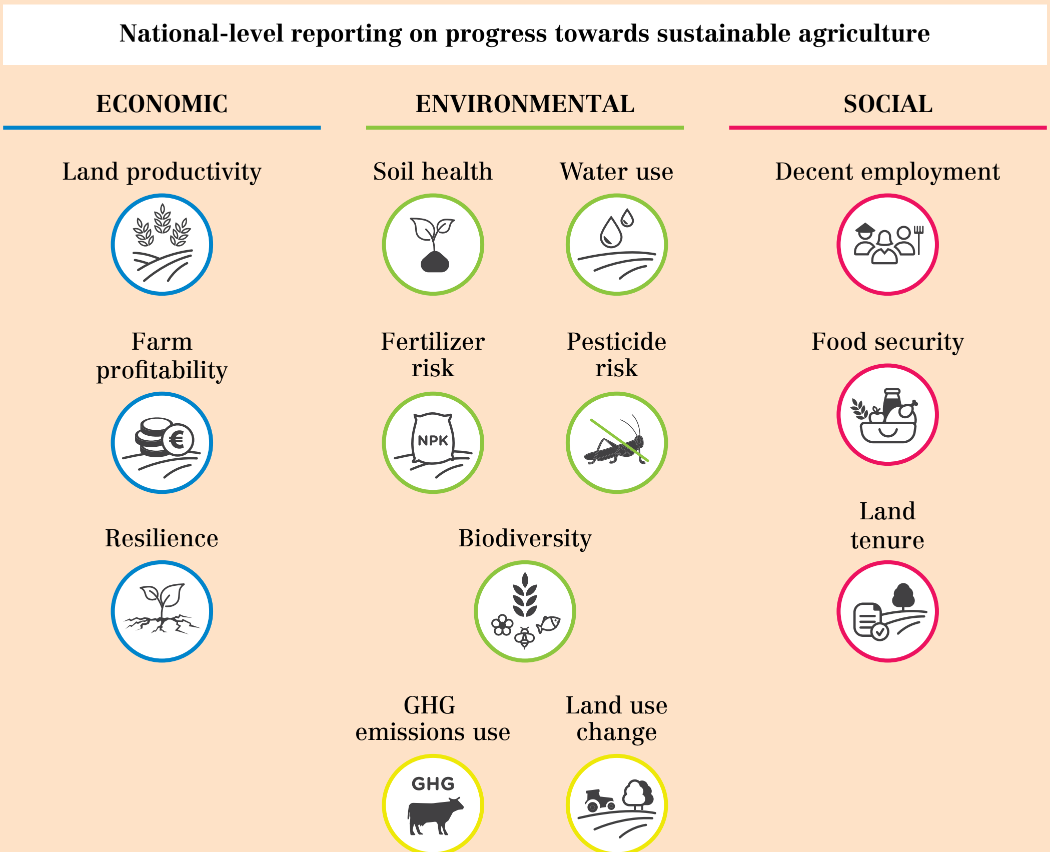
The particular mix of actions required to achieve progress towards sustainable agriculture depends fundamentally on the particular agro-ecological and socio-economic conditions of countries. There is *no one-size-fits-all* approach to promoting sustainable agriculture. However, in all cases, a development pathway towards sustainable agriculture depends on effective dialogue between stakeholders, including governments, the private sector (including farmers) and civil society.

1 Introduction

The Progress towards Sustainable Agriculture (PROSA) initiative seeks to complement ongoing efforts to monitor progress on SDG indicator 2.4.1 and to support country-level assessments using national-level data that is already available. As part of this initiative, this technical study examines in detail the key factors that are driving changes in the indicators of sustainable agriculture, to provide evidence-based insights into the key actions required to transition towards a more sustainable agricultural development pathway.

Productive and sustainable agriculture has been defined holistically through a global consultative process, leading to the approval of 11 sub-indicators that seek to capture the complexities of the economic, environmental and social dimensions of sustainable agriculture (Figure 1; FAO, 2019a). The PROSA indicators employed in this study follow the SDG indicator 2.4.1 framework as closely as possible, to compare countries' progress across economic, environmental and social dimensions of sustainable agriculture using the breadth of data available at the Food and Agriculture Organization of the United Nations (FAO) and reported by its Member Countries.

FIGURE 1 The multiple dimensions of sustainable agriculture included in PROSA



Note: PROSA considers GHG emissions and land use change as additional indicators, under the environmental dimension of sustainability in agriculture.

Source: FAO, 2019a.

The results of the analysis provide guidance to national and international decision makers on charting appropriate sustainable development pathways. Achieving the sustainable agriculture development pathways will not be easy, and will require navigating complex trade-offs and building upon synergies across the economic, environmental and social dimensions of sustainable agriculture.

The study starts with a brief discussion of the conceptual framework underlying the analysis and introduces the indicators. Section 2 identifies five key global factors driving the trends in PROSA indicators through a comprehensive mixed-method approach. Sections 3 to 8 explore the resulting drivers in detail, to provide policy recommendations on how best to advance long-term socially, environmentally and economically beneficial outcomes in the agricultural sector. Country case studies are offered throughout the text to highlight examples of innovative and effective policies and strategies.

2 A conceptual framework towards assessing sustainability in agriculture globally

KEY MESSAGES

- To account for socio-economic and agro-ecological heterogeneity, countries are grouped according to the variations in their key factor endowments, including land, labour and capital.
- The PROSA indicators enable the measurement and analysis of progress towards sustainable agriculture in case of insufficient data to measure the sub-indicators of SDG indicator 2.4.1 directly.
- A mixed-method approach has been developed – the PROSA Global Assessment – that allows for identifying the key drivers of sustainable agriculture.
- The five driver categories are: demographic factors (population dynamics, particularly related to demographic shifts and rural-urban changes); inequalities in the distribution of income and access to resources (particularly, gender-related inequalities); structure of the farming sector (average farm size, degree of mechanization); integration of the agricultural sector into the global economy; and composition of governmental support to the agricultural sector.

Two key challenges complicate the measuring and analysis of progress towards sustainable agriculture at the global level. The first is related to the tremendous socio-economic and agro-ecological diversity that exists between and within countries. This diversity leads to substantial variation in terms of the specific actions that should be prioritized, the trade-offs that must be managed and the sorts of challenges and opportunities that exist when charting a more resilient and sustainable agriculture development pathway. The second challenge relates to identifying the next-best options for measuring progress towards sustainable agriculture, given that in most cases, the data collection systems needed to directly measure the sub-indicators of SDG indicator 2.4.1 are not in place.

This section provides details on how the PROSA framework addresses these two challenges. Section 2.1 discusses the ways in which variations in the key factor endowments, including land, labour and capital influence the appropriate and feasible actions required to guide development pathways, drawing on the FAO Principles of Sustainable Food and Agriculture. These variations are operationalized through the development of a country typology that is used throughout the report to disaggregate global trends and drivers of sustainable agriculture indicators. Section 2.2 addresses the second challenge by describing the process followed to construct the PROSA indicators in order to enable the measurement and analysis of progress towards sustainable agriculture.

2.1 Multiple pathways towards more sustainable agriculture: an applied typology of agrifood systems for global monitoring and analysis of progress towards sustainable agriculture

FAO identifies five Principles of Sustainable Food and Agriculture (see Box 1) that provide a common vision for sustainable agriculture and practical guidelines for how the global community can strive to achieve it (FAO, 2014). These Principles inspired the development of SDG indicator 2.4.1 and underpin the analysis framework offered by PROSA. The five principles are meant to be applicable to all country contexts, although they fully recognize that specific pathways to sustainability exist due to important heterogeneity of the agro-ecological, political and socio-economic conditions across and within countries. In particular, variations in endowments of land, labour and capital in agriculture will influence the type of pathways towards more sustainable agriculture that are most feasible and appropriate in any given country context.

Understanding how differences in factor endowments may influence the pathways to achieving the Principles are key in monitoring and analysis of the progress made towards sustainable agriculture. A country typology that accounts for some of the critical heterogeneity between countries may help facilitate a global analysis. Such a typology can help unpack differences in trends associated with the monitoring of sustainable agriculture, the drivers of these trends, and the diversity of trade-offs and opportunities that policymakers must navigate to make progress along the sustainability pathways while respecting national and regional specificities.

BOX 1 Five principles of sustainable food and agriculture of FAO

Principle 1 recognizes that improving efficiency in the use of resources is crucial to sustainable agriculture. This includes natural resources, such as land, water and soil; human resources (labour); and capital resources, such as equipment, technologies, buildings and infrastructure. Priorities to improve resource efficiency will vary considerably by country, depending on the relative scarcity or abundance of these production factors. Countries characterized by farm systems that are abundant in labour, but scarce in capital and natural resources, will need to support labour-intensive practices to maximize returns from the other production factors. For example, some crop intensification systems may help to improve non-labour input use efficiency, yet may also require more labour compared to traditional practices. While such technologies are well suited to labour-abundant agricultural systems, they may not be appropriate in countries with limited farm labour due to the presence of competitive off-farm employment opportunities. In countries where labour is constrained, farmers are more likely to adopt labour-saving approaches to improve resource efficiency.

Principle 2 states that agricultural sustainability requires direct actions to conserve, protect and enhance natural resources. Appropriate and feasible strategies for improving natural resource conservation while maintaining or increasing agricultural production levels will vary, depending mainly on a country's relative factor endowments. Countries with large rural populations and growing land

BOX 1 (cont.) **Five principles of sustainable food and agriculture of FAO**

constraints must manage trade-offs between the conservation of natural habitats and the demand for agricultural land. These trade-offs may be less pronounced in land-abundant countries with relatively smaller rural populations, as they may find it more feasible to adopt land-sparing approaches that entail removing land from production and setting it aside for conservation. In contrast, in land-constrained countries, land-sharing practices that incorporate natural habitats into production systems, such as integrated agroforestry systems, are likely to be more successful.

Principle 3 of sustainable agriculture calls for protecting and improving rural livelihoods, equity and social well-being. This principle highlights the importance of an inclusive agricultural development process to the sustainability agenda, which provides for human needs while yielding socially equitable outcomes along all stages of the agrifood system. In capital-rich countries dominated by large-scale commercial farm operations, actions to improve conditions for agricultural labourers through wage policies and workplace safety standards are critical. Conversely, in countries dominated by owner-operated family farms, ensuring that agricultural policies are well targeted to the needs of both relatively poor and better-off farmers is essential. In all cases, investment in human capital – including in health, education and training – is key.

Principle 4 draws attention to the importance of enhancing the resilience of people, communities and ecosystems for sustainability of agriculture. Agriculture depends fundamentally on the interaction between natural, economic and social systems. As such, it is exposed to a wide range of environmental and human-induced risks and hazards. Building resilience to these risks and hazards is critical for ensuring continued conservation of and benefit from agro-ecosystems. The range of hazards and risks facing farmers, and their capacity to cope with and mitigate them, varies considerably. In more capital-intensive, industrial countries with well-developed financial and insurance sectors, farmers have greater access to a wide range of capital-intensive risk management instruments, including insurance and farm credit. Conversely, in more labour-abundant, poor countries where access to risk management tools are limited, farmers may be more dependent on localized resilience strategies, such as livelihood or crop diversification.

Principle 5 of sustainable agriculture requires responsible and effective governance. In many ways, this principle overarches the preceding four and is a critical factor in the implementation of policies and strategies to achieve more sustainable agriculture across all countries. Effective governance at all levels is required to mediate trade-offs and enhance synergies between the principles of sustainable agriculture and their associated indicators. Governance systems that facilitate effective and inclusive dialogue between stakeholders – including governments, the private sector and civil society – and make a concerted effort to ensure that the voices of the poor and marginalized are heard, are critical for sustainable agriculture.

These five principles provide policymakers with a holistic framework for assessing strategies and identifying policy options for guiding agriculture towards a more sustainable pathway. Decision-making that considers these principles is necessary for global progress towards this common vision of sustainable food and agriculture.

Source: FAO, 2014.

Several country typologies developed by the international community exist that group countries according to their various characteristics, including for the food and agriculture sectors. These include the food systems typology developed by the High-Level Panel of Experts on Food Security and Nutrition (HLPE, 2017), the per capita income groupings used by the World Bank, the United Nations Development Programme (UNDP) Human Development Index, the UN Department of Economic and Social Affairs (UN DESA) country classification, and the FAO Low-Income Food-Deficit Countries list (LIFDC). These typologies provide useful insight into the social and economic conditions of countries, as well as broader insights into agricultural supply chains and nutritional outcomes, such as in the case of the HLPE food systems typology. However, they do not explicitly focus on factors of agricultural production, which are key for assessing sustainable agriculture features.

The typology applied in this report follows the typology of agrifood systems developed in Campanhola and Pandey (2019), which focuses on agricultural-sector factor endowments and is applied at the national level. Countries are grouped based on factor productivities and relative intensities within agriculture – for land, labour and capital – to account for differences in food and agricultural production systems. The typology incorporates other recognized typologies as a second-level evaluation criteria for a country's classification. The methodology used to group countries is summarized in Box 2.

Based on well-established quantitative methods using national data, four country groups emerge according to factor productivities and relative factor endowments (Figure 2). These groups overlap well with the following agrifood typology groups developed by the HLPE (2017): Traditional Agrifood Systems, Modern Agrifood Systems and Mixed Agrifood Systems that are in transition between Traditional and Modern Agrifood Systems. However, to better account for agriculture-specific differences, PROSA further divided this group into the Mixed Agrifood Systems group into Capital-intensive and Land-intensive Agrifood Systems.

BOX 2 PROSA methodology to group countries

The approach adopted in this report builds on the global-level country typology developed in Campanhola and Pandey (2019), which provides clear linkages with the FAO Five Principles of Sustainable Agriculture when assessing suitable development strategies based on country groups. This agrifood systems typology is based on the relative abundance of the main factors of production: labour, land and productive capital. In Campanhola and Pandey (2019), the geographic areas were classified using a relatively fine spatial resolution with associated information on the three factor endowments, leading to the identification of three broad agrifood system groups: extensive (land-intensive), labour-intensive and or capital intensive. Three intermediate groups that fall between these broader categories were also established: extensive and capital-intensive systems, labour- and capital-intensive systems, and extensive and labour-intensive systems.

PROSA is designed to provide country-level insights. Therefore, it requires a typology that builds on national-level data. As the data used in Campanhola and Pandey (2019) cannot be easily aggregated to a national level, the methodology has been adjusted to draw on already-available national-level data to build country-level groupings.

Four data sets were used to quantify agricultural-sector factor endowments and intensities at national level:

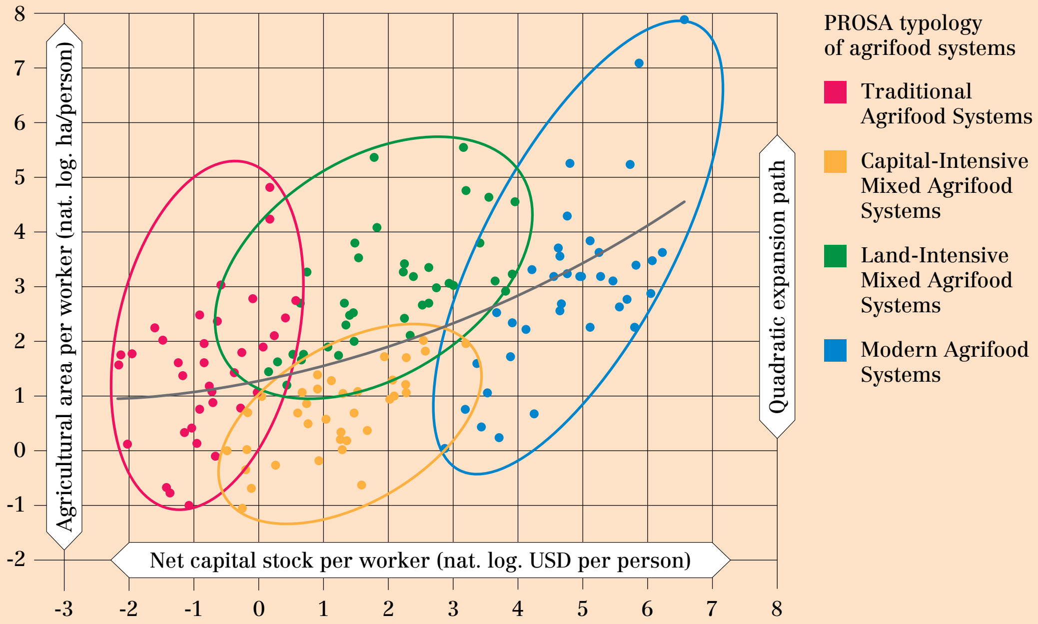
- capital endowments in agriculture from FAOSTAT, which tracks Net Capital Stocks (Agriculture, Forestry and Fishing) at country level;

BOX 2 (cont.) PROSA methodology to group countries

- land statistics from FAOSTAT's country-level data series on agricultural land;
- labour in the agricultural sector from the International Labour Organization (ILO), which estimates the number of people employed in agriculture at a national level, including both paid and self-employment; and
- agricultural value added, which is the common numerator for all factor productivity calculations, again from FAOSTAT.

Using these data, partial agricultural factor productivities were constructed for each country by dividing the agricultural value added by agricultural land, labour and capital. A principal component analysis was then applied to derive the first principal component, which combined the three factor productivities into an index variable. The resulting variable was split into quartiles to ensure that: (1) the resulting country groups are sufficiently homogeneous in terms of their agricultural production system characteristics; and (2) the number of individual countries in each group are large enough to identify patterns in the data. The group in the first quartile consists of countries in Modern Agrifood Systems, while the fourth quartile consists of countries in the Traditional Agrifood Systems. Countries in the second and third quartile were less easy to separate into homogenous groupings. Given that factor intensities of capital and land are likely to influence the suitable pathways to sustainable agriculture, the differences between countries in capital per worker and land per worker were used to create two more homogenous groups. A quadratic expansion path was applied, forming the Capital-intensive Mixed Agrifood Systems and Land-intensive Mixed Agrifood Systems groupings.

FIGURE 2 Grouping of countries by capital and land intensities (log scale) per worker



Source: Authors' own elaboration, based on data from FAO (2019b).

Countries within each of the resulting four groups share the following broad characteristics.

Countries in Traditional Agrifood Systems (green) are characterized by low labour and land productivity and low capital stocks. Within this country group, farming is the main source of livelihoods; however, the marginal productivity of agriculture is low due to an abundance of labour and severe capital constraints. These constraints are reflected in lower land productivity than may be seen in countries within Capital-Intensive Mixed Agrifood Systems and Modern Agrifood Systems, and in lower agriculture value added with relatively little increase over time. Among the countries of this group are Afghanistan, Nicaragua and the Niger. Many of these countries are also categorized as low-income food deficit countries, according to FAO, and require increases in agricultural productivity and investment to address degrading agricultural soils and meet growing food needs.

Countries with Capital-Intensive Mixed Agrifood Systems (orange) are characterized by higher land productivity and agriculture value added, due to higher levels of capital endowment per worker compared to countries within Traditional Agrifood Systems. The broader economy diversifies into services and industry, resulting in a lower agriculture share of gross domestic product (GDP) and employment. In these countries, economic growth is based primarily on capital-intensive agriculture, often substituting for labour. Countries in this group include Ecuador, Ghana and Thailand.

Countries with Land-Intensive Mixed Agrifood Systems (yellow) are also characterized by higher productivity compared to the traditional group, chiefly due to larger land areas being available to the agriculturally active population. Agriculture's contribution to GDP and employment is decreasing due to diversification of the economy as a whole; however, land productivity is lower and increasing at a slower rate compared to countries within Capital-Intensive Mixed Agrifood Systems. Agricultural growth in this group is based on higher land-use intensities than capital intensities, because of a greater abundance of land, which in turn leads to more extensive farming systems. The Russian Federation, South Africa and Uruguay are examples of countries within Land-Intensive Mixed Agrifood Systems.

Countries with Modern Agrifood Systems (blue) are capital-intensive with high land or labour productivities. Due to mechanization and access to modern technologies, agriculture is highly competitive. Many of the countries are large exporters. The countries in this group typically have a higher agriculture value added, but the overall contribution of agriculture to the diversified economy is smaller. Examples of countries within Modern Agrifood Systems are Argentina, Australia and Japan. In most of these countries, agricultural productivity is high and food insecurity is low, shifting the priority towards ensuring that agriculture is increasingly environmentally sustainable and socially just.

This applied typology of agrifood systems is used to enhance understanding of country-level differences in terms of the drivers of sustainable agriculture, and the assessment of suitable strategies within this report. The list of countries in each group is available in Annex 1.

2.2 Measuring and analysing sustainable agriculture at the national level: identifying PROSA indicators of sustainable agriculture

Over the past 30 years, the definition and measurement of sustainable agriculture has been much debated. According to the 2030 Agenda for Sustainable Development, the performance of all sectors, including agriculture, must be assessed against the three dimensions of sustainability: economic, social and environmental. In 1988, FAO defined sustainable agriculture as "the management and conservation of the natural resource base, and the orientation of technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs for present and future generations. Such development conserves land, water, plant and animal genetic resources, is environmentally non-degrading, technically appropriate, economically viable and socially acceptable". Until recently, however, there has been no internationally agreed method to measure sustainable agriculture. The SDG process created the opportunity to develop a commonly accepted measurement method. SDG target 2.4 requires that by 2030, countries "ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality". During a meeting in November 2018, the Inter-agency and Expert Group on SDG Indicators (IAEG-SDGs), which governs the overall SDG monitoring process, endorsed the methodology relating to SDG indicator 2.4.1, which operationalizes an internationally agreed definition of sustainable agriculture developed through an international and multi-stakeholder process by experts and government officials under the coordination and lead of FAO (FAO, 2019a).

SDG indicator 2.4.1 is defined as the percentage of agricultural area under productive and sustainable agriculture. This definition spans the three dimensions of sustainability, capturing the main issues that are expressed in SDG target 2.4: resilience, productivity, ecosystem maintenance, adaptation to climate change and extreme events, and soils. Eleven themes and associated sub-indicators form the basis of SDG indicator 2.4.1 (see Table 1). They include land productivity (farm output value per hectare), profitability (net farm income), resilience (risk mitigation mechanisms), soil health (prevalence of soil degradation), water use (variation in water availability), fertilizer (pollution risk and management of fertilizers), pesticide risk (management of pesticides), biodiversity (use of biodiversity-supportive practices), decent employment (wage rate in agriculture), food security (food insecurity experience scale), and finally, land tenure (secure tenure rights to land).

Sustainable agriculture can be assessed at different scales, from the farm level to the regional and national levels. The global community has agreed to measure progress within the 11 sub-indicators of SDG indicator 2.4.1 through a recently introduced farm survey as the main data collection instrument (FAO, 2018a). Many countries are still developing data collection systems to monitor these sub-indicators. The PROSA framework, therefore, develops a set of indicators using currently available data at the national level to report on progress, while data systems for reporting on SDG indicator 2.4.1 are being developed. Furthermore, the PROSA framework expands the progress monitoring scope, to include land use change in agricultural and forest areas, and GHG emissions from agriculture.

The PROSA indicators were selected based on the following criteria: (1) they are measurable with data managed by FAO; (2) data are available at the national level with country-wide and time-series coverage; (3) the data required are accessible free of charge; and (4) the data will be updated through a regular country reporting system, for future monitoring. These indicators follow the sub-indicators of indicator 2.4.1 as closely as possible and respect the sub-indicators' scope of agricultural production ending at the farm gate. Annex 2 includes a detailed description of how the indicator was constructed, the data sets used and the relevant limitations. One of the 11 sub-indicators, secure rights to land, cannot be measured following these criteria due to a lack of comparable national-level data. The PROSA indicators corresponding to the SDG sub-indicators of indicator 2.4.1 are summarized in Table 1. The sub-indicators of indicator 2.4.1 are to be monitored at different time intervals depending on the nature of the indicator, which can be applied similarly to the PROSA indicators. For example, farm output value per hectare is measured annually, while prevalence of water availability is measured every three years as its effects occur in the longer term.

BOX 3 What encompasses agriculture in the PROSA framework?

The PROSA framework attempts to adhere as closely as possible to the definition of "agriculture" in SDG indicator 2.4.1, including land used to produce food and non-food crop and livestock products, as well as agroforestry and aquaculture, to the extent that production takes place within the agricultural area. Where the agriculture, forestry and fishery sectors could not be disaggregated to include only activities that take place on agricultural land, all three were included in the measure. The term "farmers" encompasses all producers across these sectors.

TABLE 1 The PROSA indicators of sustainable agriculture measured at the national level

Dimension	Theme	2.4.1 sub-indicator	PROSA indicator	Data source
Economic	Land productivity	Farm output value per hectare	Gross production value of crops and livestock products (constant 2004–2006 USD) per agriculture area (1 000 ha)	FAOSTAT (FAO, 2019b)
	Farm profitability	Net farm income	Net production value of crops, livestock and aquaculture products (constant 2004–2006 USD 1 000) per rural population (1 000 persons)	FAOSTAT and FishStat (FAO, 2019b)
	Resilience	Risk mitigation mechanisms: access to or available credit and insurance, on-farm diversification (value of production)	Credit to agriculture, forestry and fishing (value in USD) per rural population (1 000 persons)	FAOSTAT (FAO, 2019b)
			Gini-Simpson crop and livestock diversification index (gross production value) aggregated at the national level. ** No globally comparable data on diversification at the farm level is available*	FAOSTAT (FAO, 2019b)

TABLE 1 (cont.) **The PROSA indicators of sustainable agriculture measured at the national level**

Dimension	Theme	2.4.1 sub-indicator	PROSA indicator	Data source
Environmental	Soil health	Prevalence of soil degradation	Rural population on all degrading agricultural land (% change, 2000–2010)	Barbier and Hochard, 2016
		Nitrogen balance	kg N per ha of agricultural land	FAOSTAT (FAO, 2019b)
	Water use	Variation in water availability	**Water use efficiency:** Gross production value of crops, livestock and aquaculture products (constant 2004–2006 USD) / volume of water used by the agricultural sector (10^9 m³/year) **Water quality:** Nitrogen use in agriculture (tonnes) / volume of water used by the agricultural sector (10^9 m³/year) Nitrogen use in agriculture (tonnes) / total internal renewable water resources (10^9 m³/year)	FAOSTAT, FishStat and AQUASTAT (FAO, 2019b; FAO, 2019c; FAO, 2019d)
	Fertilizer risk	Management of fertilizers: use organic sources of soil nutrients (manure or composting residues)	Manure applied to soils (kg) per area of cropland (1 000 ha)	FAOSTAT (FAO, 2019b)
		Management of fertilizers: distribute synthetic or mineral fertilizer application over the growing period Nitrogen balance	Synthetic fertilizer use (N) (tonnes) per area of cropland (1 000 ha) kg N per ha of agricultural land	FAOSTAT (FAO, 2019b)

TABLE 1 (cont.) **The PROSA indicators of sustainable agriculture measured at the national level**

Dimension	Theme	2.4.1 sub-indicator	PROSA indicator	Data source
Environmental	Pesticide risk	Management of pesticides: use one pesticide no more than two times or in mixture in a season, to avoid pesticide resistance	Pesticide use (tonnes) per area of cropland (1 000 ha)	FAOSTAT (FAO, 2019b)
	Biodiversity	Use of biodiversity supportive practices: use of synthetic pesticides	Pesticide use (tonnes) per area of cropland (1 000 ha)	FAOSTAT (FAO, 2019b)
		Use of biodiversity supportive practices: the area under a single continuous commodity is no larger than 2 hectares (excluding pasture), and areas larger than 2 hectares under a single commodity use at least two different varieties	Gini-Simpson crop, livestock and aquaculture diversification index (area harvested, livestock units) aggregated at the national level. * *No globally comparable data on diversification at the farm level is available*	FAOSTAT and FishStat (FAO, 2019b; FAO, 2019d)
Social	Decent employment	Wage rate in agriculture	Agriculture, forestry and fishing value added per worker (constant 2005 USD)	FAOSTAT (FAO, 2019b)
	Food security	Food Insecurity Experience Scale (FIES)	Prevalence of severe food insecurity in the total population (%)	FAOSTAT (FAO, 2019b)
	Land tenure	Secure rights to land	*No globally comparable data at the national level are available, further efforts are needed*	

TABLE 1 (cont.) **The PROSA indicators of sustainable agriculture measured at the national level**

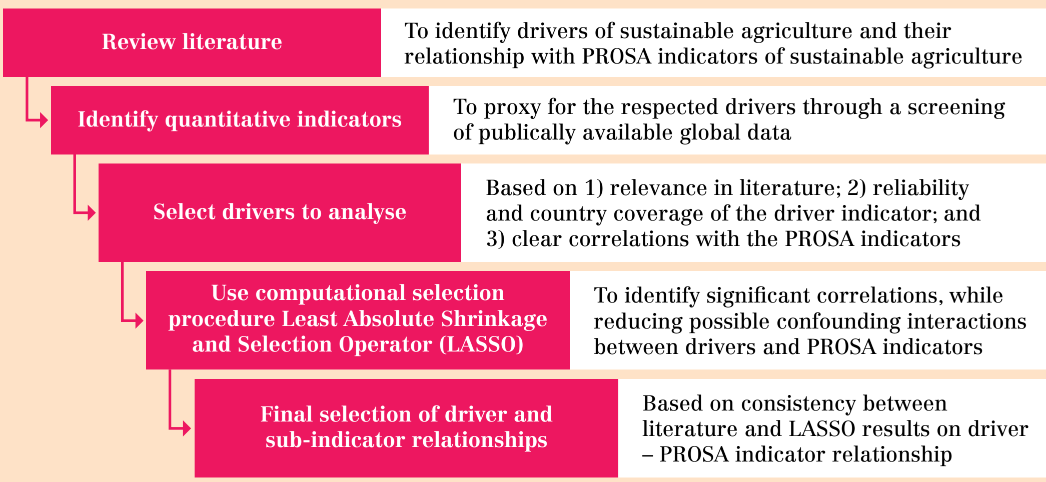
Dimension	Theme	2.4.1 sub-indicator	PROSA indicator	Data source
Additional	GHG emissions	** added for national-level monitoring*	GHG emissions (CO_2 eq) intensity from crops and livestock	FAOSTAT (FAO, 2019b)
	Land use change	** added for national-level monitoring*	Change in agricultural area and forest area over time	FAOSTAT (FAO, 2019b)

Source: Authors' own elaboration.

2.3 Identifying drivers of change on the path towards sustainable agriculture

To achieve sustainable agriculture, decision makers in the public and private sectors require insights into how major drivers of change in agriculture affect progress across economic, social and environmental dimensions. While there is considerable research identifying important driving and constraining factors to achieving sustainability in agriculture, the study distinguishes five global driver groups that affect the multiple dimensions of sustainable agriculture, using SDG indicator 2.4.1 as guidance. It then provides an empirical analysis of the important relationships between drivers and the PROSA indicators of sustainable agriculture. To do so, this report develops a comprehensive analytical approach, hereafter referred to as the PROSA Global Analysis. This approach adopts a multistage mixed method framework to identify key drivers, and specific relationships with the sustainable agriculture indicators that are empirically robust, conceptually valid, and relevant to policy interventions. The PROSA Global Analysis approach entails five steps which are summarized in Figure 3 and described in more detail in Annex 2.

FIGURE 3 **Five steps of the PROSA Global Analysis**



Source: Authors' own elaboration.

Step 1. Review literature

The initial identification of potential factors that drive sustainable agricultural outcomes began with an extensive review of empirical and theoretical studies, combined with thematic expert consultations within FAO and beyond. The literature on the factors that influence the sub-indicators of SDG indicator 2.4.1 on sustainable agriculture are generally country-specific, often survey-based, and frequently focus on the sub-national level. In total, literature on 68 drivers of agricultural change and sustainability was reviewed at this stage of the analysis, and the relationship of the drivers with SDG indicator 2.4.1 were summarized.

Step 2. Identify quantitative proxies for the drivers

The next step was to screen the publicly available data to identify quantitative variables to proxy the respective drivers. In most cases, several measurements were possible. Inequality, for instance, can be measured in terms of distribution of income or resource ownership within the general population, of the concentration of these resources among a sub-segment of the population, of the difference between genders. In the case of income inequality, the Gini coefficient is a popular and widely available measure, which is also used to construct combined indexes such as the Inequality-adjusted Human Development Index (IHDI). Where multiple potential proxies of drivers of agricultural change exist, they are often highly correlated. This creates analytical challenges when assessing independent relationships between drivers and indicators of sustainable agriculture, and therefore require a reduction in the number of driver proxies. The selection of driver proxies to include in the subsequent empirical analysis was largely based on their availability, country coverage and ease of interpretation.

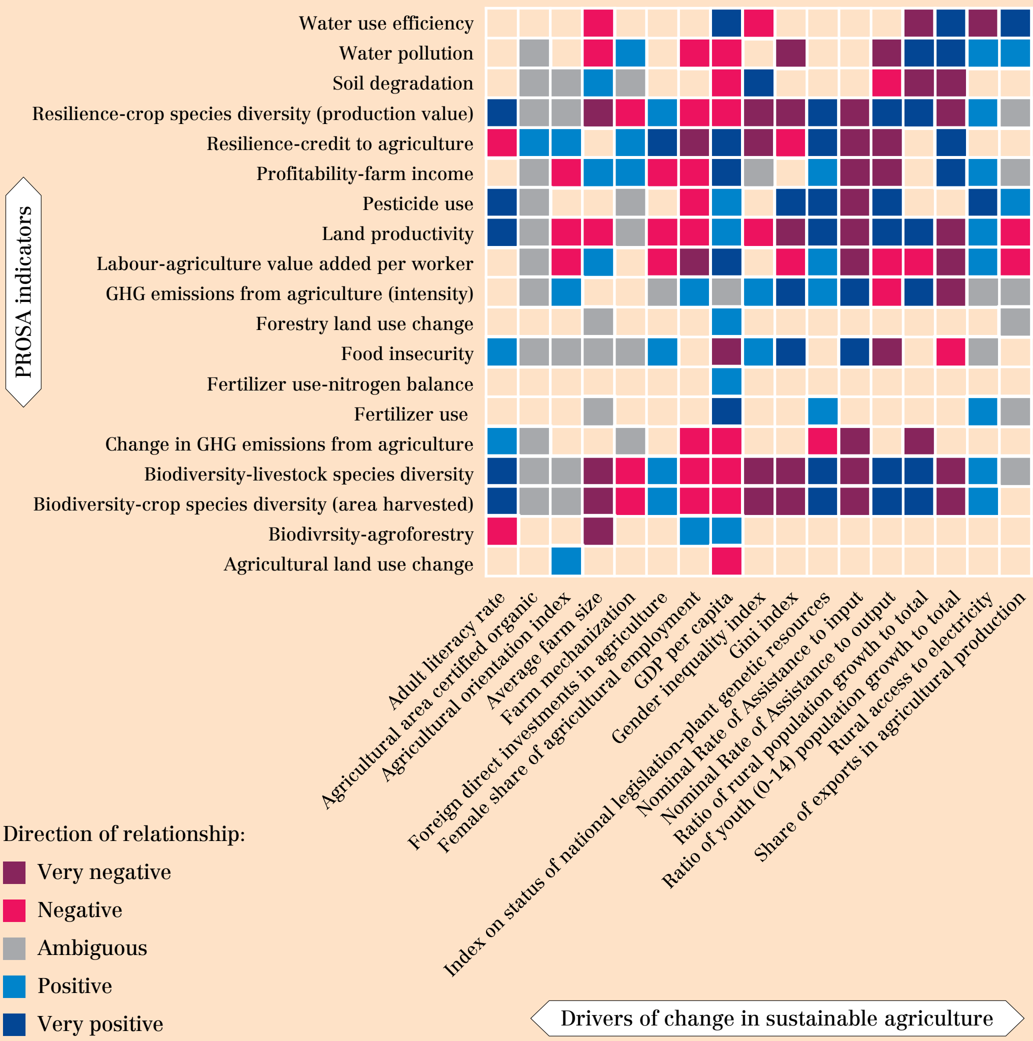
Step 3. Select drivers to analyse

Through the literature review and the screening of available global data to proxy for each of the identified potential drivers, the list of potential drivers was reduced from 68 to 17. To organize and analyse this diverse set of drivers, a clustering procedure was used to identify five broad categories based on thematic groups identified in the literature. This clustering process helped refine the selection of drivers to include in the final analysis and to organize the overall structure of the PROSA report. The five driver categories are:

1. demographic factors (population dynamics, especially related to demographic shifts and rural-urban changes)
2. inequalities in the distribution of income and access to resources (particularly, gender-related inequalities)
3. structure of the farming sector (average farm size, degree of mechanization)
4. integration of the agricultural sector into the global economy
5. composition of government support to the agricultural sector

From the list of 17 drivers, the literature on their relationships with each PROSA indicator of sustainable agriculture is summarized according to the general magnitude and direction of the relationships, from very positive to very negative. However, the context-specificity of many relationships between the PROSA indicators and the drivers of change found in the literature creates numerous challenges for generalizing the results. For example, much of the literature highlights a negative relationship between rural population growth rates and land degradation; however, under certain contexts, the opposite can occur (Lambin and Meyfroidt, 2001). In these cases, where the general tendency in the literature is in a particular direction, but alternative evidence is found, the result is labelled as either positive or negative. By contrast, if the results are consistently in one direction, evenly split or highly context-specific, the result is summarized as very positive (negative) or ambiguous, respectively. Figure 4 summarizes the literature-based ranking exercise of drivers for a subset of drivers considered at this stage of the PROSA Global Analysis.

FIGURE 4 Selected relations between drivers and PROSA indicators, based on the literature review



Note: The Nominal Rate of Assistance (NRA) to input and NRA to output measure government support to agricultural input use and commodity production that increase (or decrease) farmer income, expressed as percentage of income in a no-policy situation.

Source: Authors' own elaboration.

Step 4. Empirical analysis using a computational selection procedure

The list of 17 drivers of agricultural change identified in the third step of the PROSA Global Analysis was further refined through the Least Absolute Shrinkage and Selection Operator (LASSO) empirical approach. This approach is designed to select a small number of independent variables – in this case, the drivers of agricultural change – from a wide range of potential options (see Annex 2 on the formal specification of LASSO procedure). This approach allows for the selection of drivers of agricultural change that exhibit quantitatively significant relationships with the PROSA indicators of sustainable agriculture, while addressing many of the empirical challenges that may confound an assessment of these relationships at a national scale.

In particular, a fundamental challenge for the empirical identification of PROSA indicator-driver relationships is that, in principle, each of the 17 potential drivers identified in the first steps of the selection process can influence each PROSA indicator. This causes several difficulties for standard econometric approaches, including multi-collinearity between drivers, the possibility of reverse causality and thus identification problems, and over-specification due to the inclusion of a large number of independent variables (drivers), some of which have incomplete observations.

The empirical approach chosen in the PROSA framework is typical of computational methods in the machine-learning domain, and is designed to address the challenges of model selection faced in this analysis. The key advantage over conventional econometric methods is that it can exclude drivers from the estimation model for each PROSA indicator, when data is incomplete.[1] Overall, the results from the LASSO procedure provide a more comprehensive picture of the empirical relationships between drivers and PROSA indicators of sustainable agriculture, and can help complement the literature review's selective results.

Step 5. Final selection of driver and indicator relationships

The final selection of drivers of agricultural change included in this paper was carried out by layering the empirical results of the PROSA analysis over the consolidated analysis of the literature. In this last step, the pairwise relations of each driver and sustainable agriculture PROSA indicator were reviewed. The final selection of relationships that is examined in this report was made based on the following criteria. First, a significant relationship was identified through LASSO, suggesting an empirical association between the driver and the PROSA indicator variable of sustainable agriculture. Second, the direction of this empirical relationship (i.e. positive or negative) was found to be supported by existing literature, and is thus conceptually justified under certain conditions.

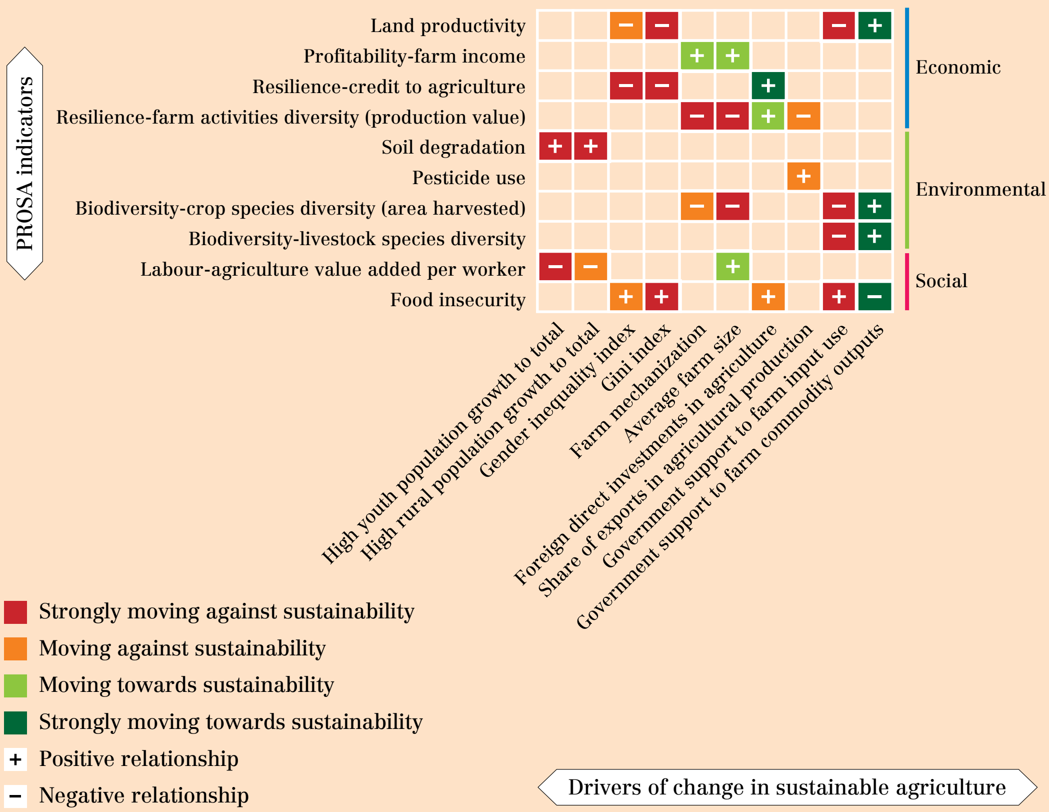
At this stage, it is important to note that the drivers and driver-PROSA-indicator relationships analysed in this study are not comprehensive. This study focuses on quantitative driver indicators that: (1) have strong global coverage; (2) can be influenced directly by policies; and (3) can be meaningfully aggregated to the national level. Critical biophysical drivers of agricultural change, such as rainfall, temperature and soil nutrient content are not considered, as they would require biophysical modelling that exceeds the scope of this analysis. Moreover, this study does not analyse the ways in which the PROSA indicators of sustainable agriculture drive other PROSA indicators. For example, pesticide use can drive loss in biodiversity which can in turn drive food insecurity. To this end, this analysis is fully aligned with the methods relating to SDG indicator 2.4.1, regarding which each of the 17 indicators representing the drivers and the PROSA indicators are assumed to be independent. Finally, while each driver affects all of the PROSA indicators directly or indirectly, the report does not attempt to analyse each driver-PROSA-indicator relationship. Instead, it examines those relationships found to be the most empirically and conceptually important through the PROSA Global Analysis.

Through the multiple stages of the PROSA Global Analysis, 30 separate relationships between drivers and PROSA indicators have been identified (Figure 5). Although each driver can, in principle, influence sustainable agriculture, our analysis indicates that only some of these relationships are statistically significant at the global level. However, while the size and

1 Alternative approaches to these challenges, such as the one discussed by Varian (2014), remains computationally more demanding without necessarily providing better results.

direction of these relationships hold at the global level, they may differ at the country level. In subsequent sections of this study, these global relationships are analysed to help identify and prioritize the strategies and policy options for supporting progress towards sustainable agriculture by country groups. For organizational and conceptual purposes, the sections are organized thematically, according to the five driver clusters identified in Step 3 of the PROSA Global Analysis.

FIGURE 5 **Final selection of driver and PROSA sustainable agriculture indicator relationships, based on the literature review and LASSO analysis**



Source: Authors' own elaboration.

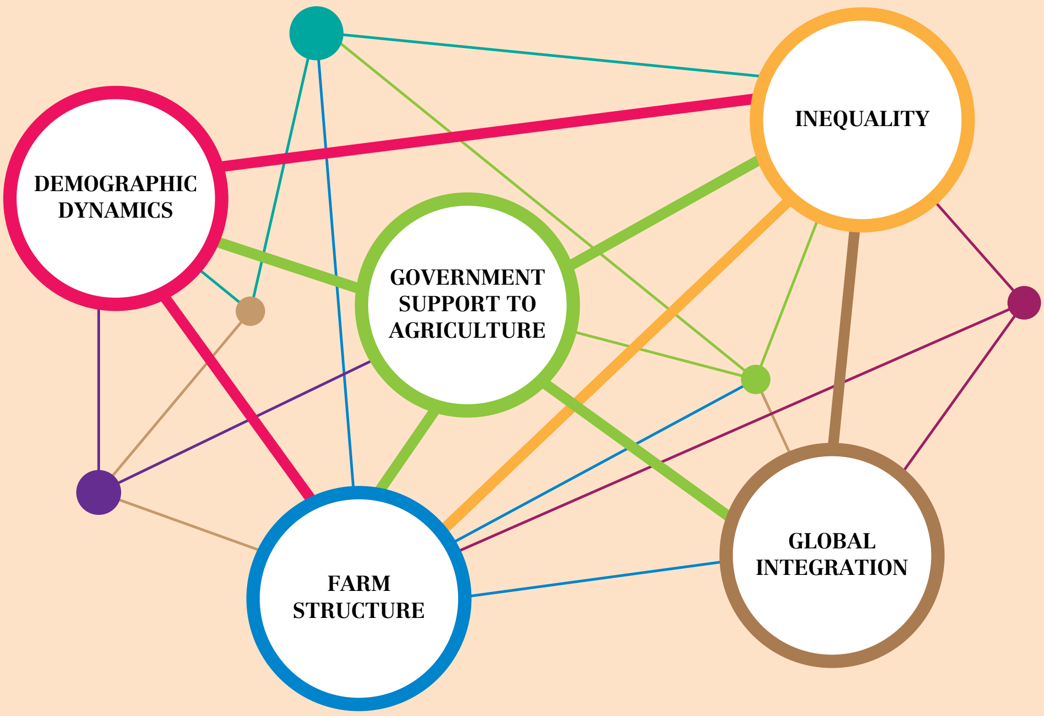
2.4 Unpacking key global drivers of change along the multiple dimensions of sustainable agriculture

The driver groups identified through the PROSA Global Analysis are explored in Sections 3 to 7 of this publication and are organized according to the five key clusters of drivers: demographics, inequality, farm structure, global integration, and government support to agriculture. The study highlights important variations in these relationships between country groups, along with strategies for advancing sustainability in agriculture.

Each driver has a direct influence on progress towards agricultural sustainability; however, the drivers are also interlinked and changes in one driver can affect others (Figure 6). For example, demographic dynamics and inequalities influence farm structure, as population densities and equality of land distribution are both key underlying determinants of farm size.

Demographic shifts can influence inequalities if growing populations of rural farmers are pushed onto marginal and degrading lands, entering a cycle of low productivity and land degradation. In turn, inequalities can be heightened by processes of global integration of agricultural sectors if foreign investment crowds out local producers and syphons land and water resources away from poorer smallholders.

FIGURE 6 Global drivers of change, interlinked in ways that are important to holistic strategies for greater sustainability in agriculture



Source: Authors' own elaboration.

Government support is one of the most important and direct mechanisms available to policymakers to encourage sustainable agricultural development, and influences all other driver groups. For example, public expenditures can support off-farm work programmes to address low wages in agriculture and degrading agricultural soils from surges in rural populations, and increase access to credit to support small- and medium-scale mechanization. Public spending on extension and access to resources in agriculture can target female-headed or lower-income households to improve gender and income inequalities. Moreover, public programmes that support access to markets and improved technologies in agriculture can help local farmers to be included in higher-value agricultural commodity markets, in the process of global integration.

The complex and interconnected nature of agriculture means that successful interventions supporting positive and reducing negative outcomes of one driver can lead to potential spillover effects in others. Understanding these linkages and how each driver affects important aspects of sustainable agriculture is key for decision makers when considering holistic strategies across drivers. The following sections aim to help decision makers optimize increasingly scarce public funds to achieve greater sustainability in agriculture.

3 Demographic dynamics

KEY MESSAGES

- In most countries with traditional agrifood systems, population growth is accelerating agricultural land expansion and soil degradation.
- A lack of jobs outside of agriculture for a growing population of young people in rural areas is leading to mutually reinforcing land degradation and low land productivity.
- Integrating job creation and sustainable agricultural intensification strategies should be a key part of any approach to make agriculture and livelihoods more sustainable.

Population growth and demographic shifts in rural areas are driving important changes in agriculture. Overall, the global population is growing and is increasingly urban and affluent, leading to an acceleration of aggregate food demand. At the same time, populations in many of the world's rural areas are becoming both smaller and older, as young people move to cities in search of non-farm employment. This pattern is well established in countries with modern systems, where prospects for remunerative off-farm employment pull young people out of rural areas and into service and manufacturing jobs. By contrast, countries with traditional systems, particularly those in sub-Saharan Africa, continue to experience rapid population growth in both rural and urban areas, expanding the already considerable number of young, rural people in need of viable livelihood opportunities.

The PROSA Global Analysis indicates that these demographic dynamics are empirically and conceptually associated with unsustainability in agriculture (Figure 7). High rates of growth in rural and youth populations are generally associated with greater soil degradation and lower wages in agriculture, measured as agriculture value added per worker as a proxy. Unpacking these important relationships and understanding how they vary between countries is key in guiding policies towards achieving more sustainable agriculture.

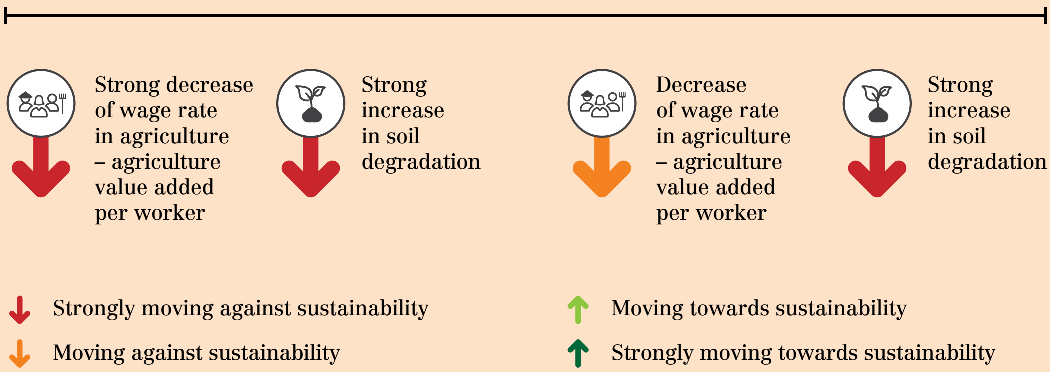
Population growth often leads to agricultural land expansion and raises concerns about the degradation of agricultural soils

Meeting the food needs of a growing and increasingly urban global population will be achieved through intensification of existing agricultural land and expansion into non-agricultural land. Which pathway dominates in a particular country is, in large part, a function of the overall availability of uncultivated, fertile land, combined with the technologies and services available to farmers (see, among many, Boserup, 1965 and Timmer, 1988). Globally, agricultural land grew from the 1970s to the 2000s, particularly in countries with Land Intensive Mixed Agrifood Systems, mirroring trends in deforestation. Countries with more limited land resources, by contrast, typically intensify production of existing land through practices that may degrade or enhance soil and other natural resources, depending on the technologies and inputs used and the land management techniques applied. This process can be seen in countries within Modern Agrifood Systems where agricultural land decreased consistently over the last five decades amid increasing productivity.

FIGURE 7 Directions of progress between demographic dynamics and key PROSA indicators of agricultural sustainability

A. HIGH YOUTH POPULATION GROWTH TO TOTAL POPULATION GROWTH

B. HIGH RURAL POPULATION GROWTH TO TOTAL POPULATION GROWTH



Source: Authors' own elaboration.

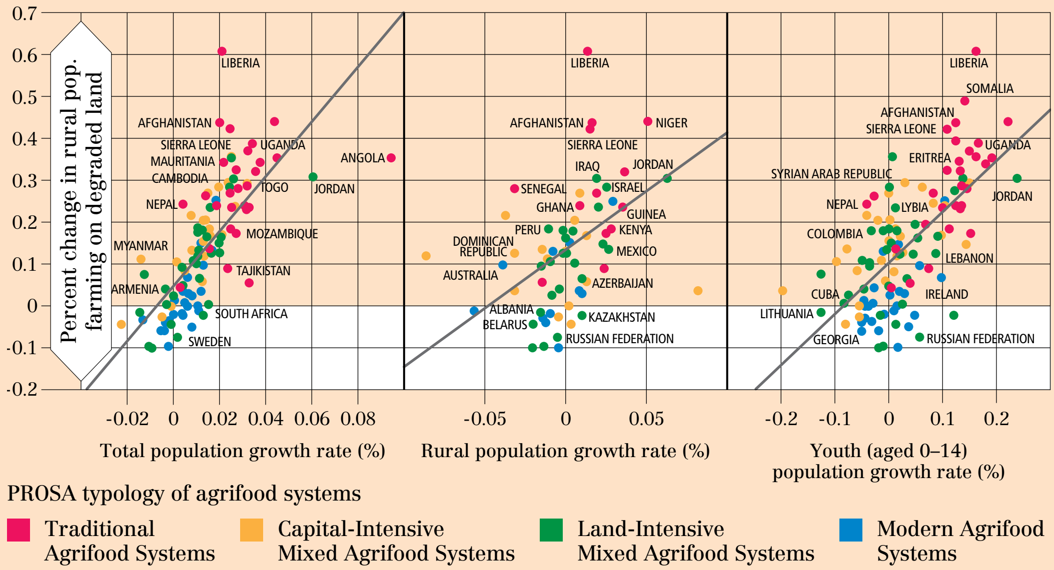
Both processes – expansion and intensification – affect the productivity of agricultural soils, the maintenance of their quality, and the overall sustainability of agriculture. Intensifying production without replenishing soil nutrients or allowing a fallow time to recover soil fertility causes further degradation. Intensification practices that build up soil-organic matter, through mulching, application of manure or compost, residue retention and reductions in soil disturbance are needed, to replenish soil nutrients and prevent further degradation. Land expansion often occurs through land conversion at the expense of forests, which are critical to environmental sustainability (FAO, 2016a). However, the availability of suitable land that can be converted to cropland is increasingly limited, due to urbanization, climate change and soil degradation (FAO, 2018).

The environmental concerns of agricultural land expansion, along with the lack of available land, make this option increasingly less viable. Yet, in capital-poor countries with growing populations, the ability to sustainably intensify production on existing farmland is limited by a lack of physical capital and institutional support, such as credit systems and extension services that can provide farmers with required tools and information.

Of all the country groupings considered in this report, countries within Traditional Agrifood Systems must manage the most pronounced population dynamics. Countries in this group have the highest rate of overall population growth, the most rapid expansion of young people in the world, and a continued expansion of agricultural lands (Table 2). This growth is strongly associated with an increase in the share of rural people living on degraded agricultural lands, suggesting that unsustainable expansion and intensification pathways dominate in these countries (Figure 8). Countries within Modern Agrifood Systems, by contrast, have a declining rural population, on average (Table 2), a trend occurring simultaneously with a decline in the rural population living on degraded land (Figure 8).

The PROSA Global Analysis suggests that growing rural populations living on degraded lands are associated with general population growth rates, rather than with the growth rate of the rural population itself.[2] This finding is partly explained by the fact that the growth rate of the rural population is composed of the growth rates of rural populations on degraded lands and on non-degraded lands. Countries with a high general population growth rate, a high degree of urbanization, and a limited availability of fertile areas may experience an expansion into less fertile lands and additional pressure on the fertility of already cultivated areas. This suggests that at the global level, when overall population growth rates exceed the rates of growth in rural areas, the proportion of populations on degraded agricultural land is higher. This relationship is apparent in the differences in the slopes in Figure 8. It is likely that this result is driven in large part by the demographic transition occurring in many counties, but that is particularly pronounced in countries within Mixed Land Intensive and Traditional Agrifood Systems. Here, urbanization growth rates are outstripping rural population growth, although rural populations are also growing (Table 2). If agricultural activities are carried out on already degraded land, poor sector performance may contribute to the migration of people from rural to urban areas, leading to higher growth rates in urban populations compared to rural ones. Furthermore, the surge in urban populations leads to a higher demand for food in urban areas, alongside an increased demand for agricultural land in rural areas. These complex dynamics may incentivize expansion into more marginal and easily degraded lands, or unsustainable intensification processes on existing land.

FIGURE 8 **Increases in total population growth, strongly associated with expansion of rural populations farming on degraded lands (2010–2016 average)**



Note: Degraded lands are defined as lands that present a negative change in net primary productivity (NPP) from 1981 to2000.

Source: Authors' own elaboration of data from Barbier and Hochard (2016), UNSD (2019) and UN DESA (2019).

2 The analysis uses data on the percent change in rural populations living on degrading agricultural land as an indicator of soil degradation. The soil nutrient balance is also an important indicator of soil quality; however, in this analysis, it did not reveal significant findings. For this reason, rural populations living on degrading agricultural land is used instead, despite presenting important limitations. In particular, the indicator is measured as the rural population in a given year divided by the degraded land in the year 2000, the only one for which data on degraded land is available. Therefore, the indicator does not take into account improvements of land quality or further land degradation that may have occurred in other years.

TABLE 2 Demographic shifts by country typology group

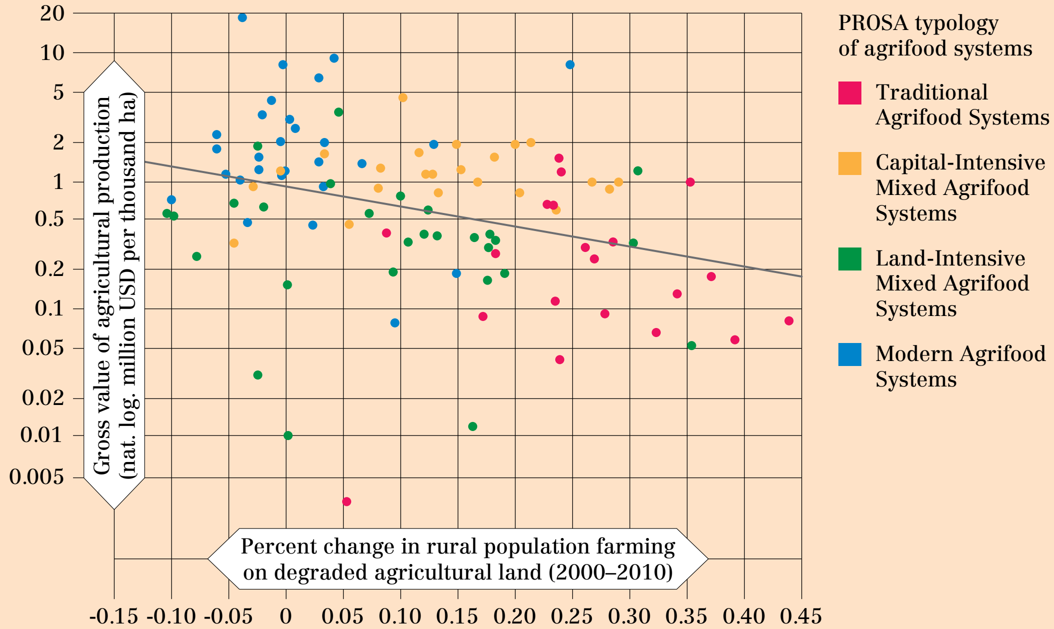
	Annual population growth rate, 2010–2016 average (%)	Youth (0–14 years) population growth rate, 2010–2015 average (%)	Rural population growth rate, 2010–2016 average (%)
Traditional Agrifood Systems	2.8	12.0	2.0
Capital Intensive Mixed Agrifood Systems	1.0	0.4	-0.9
Land Intensive Mixed Agrifood Systems	1.1	1.5	0.3
Modern Agrifood Systems	0.5	-0.4	-0.8

Source: Authors' own elaboration of data from UNSD (2019) and UN DESA (2019).

Higher land degradation coincides with lower agricultural productivity

The rapid expansion of populations living and working on degraded agricultural land is of particular concern in achieving sustainable agriculture. The increase in the share of rural populations living on degraded land is strongly associated with low levels of land productivity (Figure 9). This relationship reflects a vicious cycle, in which low levels of productivity on existing land push populations onto more marginal land in an effort to produce sufficient food. The process of land degradation is reinforced by the poor soil quality and fragile conditions of marginal land, along with farmers' constraints on accessing soil enhancing inputs (among many, Tittonell and Giller, 2013 and Barrett, 2008). Breaking the cycle of land degradation and low land productivity is crucial, especially in the Traditional Agrifood Systems.

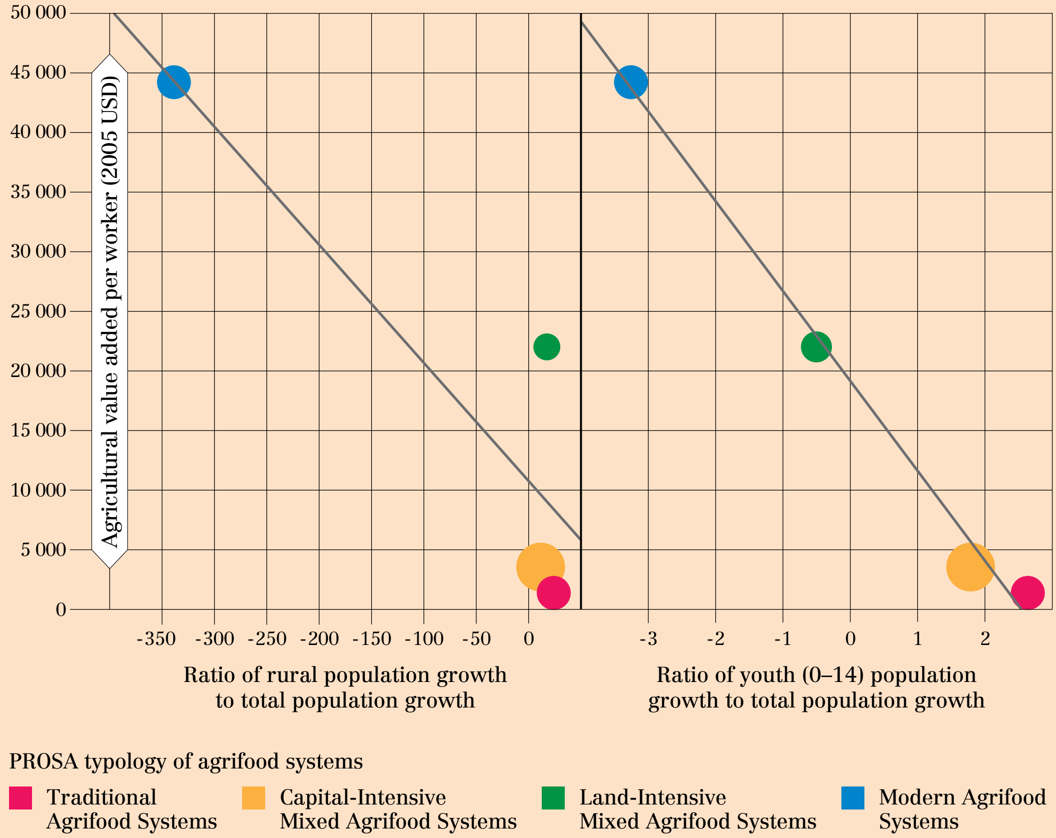
FIGURE 9 High rates of rural populations on degraded land, corresponding with low land productivity globally (2000–2016 average)



Source: Authors' own elaboration of data from Barbier and Hochard (2016) and FAO (2019b).

A growing labour force in rural areas can lead to lower overall productivity per worker and declining wages, if not met with increased non-farm job opportunities, particularly for youth (World Bank, 2013). The PROSA Global Analysis highlights a strong negative relationship between rural and youth population growth and value added per agricultural worker (Figure 10). The relationship is particularly pronounced for countries within Modern Agrifood Systems, which have, on average, declining rural populations and rapidly rising value added per agricultural worker (Table 2).

FIGURE 10 Rural and youth population growth, associated with lower labour productivity in agriculture when not met with increased off-farm and urban job opportunities (2010–2016 average)



Note: The size of the dot indicates the size of average change in the urban share of the population.

Source: Authors' own elaboration of data from FAO (2019b), UNSD (2019) and UN DESA (2019).

Two divergent development pathways can emerge in response to growth in the population of young people in rural areas. First, through the "economic transformation" process, opportunities created in the non-farm economy pull people out of rural areas into higher paying employment (Johnston and Mellor, 1961; Timmer, 1988). This leads to an increase in agricultural wages, creating incentives for farmers to replace farm labour with capital through mechanization and other intensification technologies. This process is mutually reinforcing: increased wages in the rural economy trigger demand growth for services and manufactured products purchased in the non-farm economy, while greater capital intensification of farming frees up more rural labour that enter the non-farm economy. Agriculture continues to grow, but at a slower pace than other sectors, leading to a decline in the contribution of agriculture to the country's GDP.

If there are no jobs outside of agriculture for a growing population of young people, the process of income and labour productivity results in stagnation. For example, if young people are not pulled into remunerative off-farm employment, but are instead pushed out of farming due to declining agricultural opportunities, agricultural wages are likely to remain stagnant and economic structural transformation will be less pronounced. The stagnation of labour productivity is particularly visible in countries with a high cohort of young people (World Bank, 2019). In countries within Traditional and Capital-Intensive Mixed Agrifood Systems (Figure 10), employment growth in the non-farm economy struggles to keep pace with the large number of young people entering the labour market each year. As a result, wages are often depressed, and young people are not pulled out of rural areas into remunerative non-farm employment (Losch, Fréguin-Gresh and White, 2012). This tends to keep farm wages low and limits the capacity and incentives for farmers to adopt more capital-intensive farming methods (Fox and Thomas, 2016). Under these conditions, processes of urbanization are driven chiefly by push factors, such as declining land availability and livelihoods options in rural areas (Bezu and Holden, 2014). Strategies and initiatives that simultaneously support rural job creation and improvements in long-term agricultural productivity are fundamental to capture youth dividends in countries within Traditional and Capital-Intensive Mixed Agrifood Systems.

Allocating labour towards sustainable intensification and developing off-farm employment opportunities can reduce pressure on degraded land

Minimizing the expansion and degradation of agriculture land will require a multifaceted approach, which includes the creation of more jobs outside of agriculture and more efficient use of labour within agriculture. Increasing land-use efficiency with moderate expansion of agricultural lands may be necessary in certain contexts to ensure greater food security; however, few countries have managed a land-use transition over recent decades that simultaneously increased their forest cover and agricultural production (Lambin and Meyfroidt, 2011). Successful countries have relied on various mixes of agricultural intensification, land-use zoning, environmental protection, increased reliance on imported food and wood products, the creation of off-farm jobs, foreign capital investments and remittances.

Among these, encouraging strategies that take advantage of synergies between excess labour and soil-regenerating farming practices that tend to be more labour-intensive are a critical part of the solution (Sitko and Jayne, 2018). In the Indian Himalayan Region, natural vegetation strips, combined with weed mulching and manure application, allowed farmers to increase ecosystem services (such as water retention and soil organic carbon) on their farms, and reduce production costs while enhancing crop yields (Ghosh *et al.*, 2015). In resource-constrained but labour-abundant households, the cost savings enabled by these practices makes them worthwhile to adopt, with positive environmental and economic outcomes towards a more sustainable agriculture.

Additionally, investing in on- and off-farm employment opportunities in rural areas will be critical for the growing populations of youth, as they reach adulthood and require jobs. This is especially important in countries where urban jobs are few or are located in remote areas, cut off from alternative employment opportunities. Both the public and the private sector can support rural livelihoods through investment in rural infrastructure (to better connect rural households to markets), promotion of small and medium enterprises, and technical training in remunerative agricultural and non-agricultural activities. In Bangladesh, for example, a niche market for mushrooms is providing lucrative employment for young entrepreneurs in agriculture (see Case study 1).

CASE STUDY 1 Employing rural youth through mushroom farming in Bangladesh

In Bangladesh, young farmers are developing a profitable and environmentally sustainable mushroom farming sector. One of the most densely populated countries in the world, Bangladesh is an example of a Mixed Capital-Intensive Agrifood System country facing challenges in agricultural sustainability, due to extremely limited agricultural land and high rates of unemployment (Rahman *et al.*, 2017). In particular, youth unemployment doubled from 6.32 percent in 2000 to 12.8 percent in 2017, creating a large need for employment opportunities that are attractive to rural youth with limited access to land (ILO, 2019). With the help of publicly funded training programmes, young farmers are learning to cultivate mushrooms to improve their incomes.

Mushroom farming has high financial returns and require minimal labour and capital investment and minimal land use, making it a promising sector for rural and semi-urban youth in countries such as Bangladesh. Market demand from middle- and high-income households, as well as high international demand, is making mushrooms more profitable in Bangladesh than rice or wheat, two of the most common cash crops in the country (Easin *et al.*, 2017; Imtiaj and Rahman, 2008). Mushrooms can be grown all year round, in small spaces, using recycled materials as growing substrate such as wheat and rice straw. Production requires little use of inorganic fertilizer and chemical pesticides compared to most crop and livestock farming, and the substrate can be reused as an organic fertilizer after production. Moreover, their high nutritional value makes mushrooms a viable solution to improving the protein, mineral and vitamin intake of households (Marshall and Nair, 2009).

However, mushroom farming is a relatively new crop in Bangladesh, and knowledge of production and marketing channels is limited. In 2003, the Government of Bangladesh established the National Mushroom Development and Extension Centre (NMDEC), to improve the knowledge of and attitude towards mushrooms, and act as an intermediary between mushroom farmers and wholesalers (Barmon *et al.*, 2012). Country-wide training programmes are educating farmers on proper hygiene and sterilization techniques, and raising awareness among consumers of the nutritional benefits of mushrooms. The training programmes have proven effective at improving farmer knowledge and attitudes, as well as attracting youth. A recent study of mushroom enterprises in central Bangladesh showed that 40 percent of farmers were between 20 and 30 years old (Easin *et al.*, 2017; Rahman *et al.*, 2017).

Mushroom farming maximizes synergies between reduced and recycled input use, constituting an economically attractive, as well as environmentally sustainable, option to supplementing the livelihoods of rural youth in capital- and land-constrained countries. The role of public- and private-sector organizations in countries like Bangladesh will continue to be important in maintaining this activity, including in the development of local markets and improvement of the storage and marketing of mushroom and mushroom products (Easin, 2017; Marshall *et al.*, 2009). Supporting farmers' investment in processing infrastructure and creating value-added products, such as dried or pickled mushrooms, will help farmers prevent loss of products through spoilage, and sell their product at higher prices (Marshall *et al.*, 2009).

Sources: Barmon *et al.*, 2012; Easin *et al.*, 2017; ILO, 2019; Imtiaj and Rahman, 2008; Marshall *et al.*, 2009; Rahman *et al.*, 2017.

BOX 4 Youth employment and sustainable intensification in Burkina Faso

Burkina Faso provides an example of the diverse ways in which productivity gains in staple crops alone can profoundly affect youth livelihoods. In recent years, Burkina Faso has benefited from new cereal crop varieties produced by the national agricultural research system and extended to millions of smallholder farmers through extension programmes. Cereal yields (mainly maize and rice) doubled between 1990–1995 and 2010–2014 (FAO, 2019a). This enabled farmers to produce their households' staple food needs on less land, thereby freeing up land and labour for other income-earning activities. One particularly important new activity is the growing of fodder crops; over time, this has replaced the transhumance system of sending livestock herds away during the dry season with a more intensive year-round raising of livestock locally.

The ability to integrate fodder crops into the farming system has allowed for more permanent tending of livestock; regular dairy income for many households; improved nutrition resulting from the year-round supply of dairy products; and the ability to collect manure for reintegration of organic matter back into the cereal fields. This, in turn, led to improved soil quality, better crop response to inorganic fertilizer, increasing cereal yield growth, and a further contribution to sustainable agricultural intensification. In these various ways, the success of Burkina Faso's crop science and associated investments has transformed the integrated cereal-legume-livestock systems in ways that have promoted sustainability and resilience, improved nutritional outcomes, greater profit opportunities for youth in farming, and greater multiplier effects from agricultural growth on job growth in the off-farm economy.

Source: Sitko and Jayne, 2018.

4 Inequality

KEY MESSAGES

- The unequal distribution of wealth and resources hinders agricultural productivity and economic prosperity, and undermines progress toward sustainable agriculture.
- Addressing gender-based inequalities can contribute to greater agricultural productivity and food security, particularly in countries where women's contribution to the agricultural workforce is large and growing.
- Strengthening land tenure rights among poor rural farmers is critical for addressing inequality in agriculture.
- Developing innovative strategies to improve access to credit and agricultural services for marginalized farming populations is key in lessening inequalities in agriculture and enhancing sustainability.

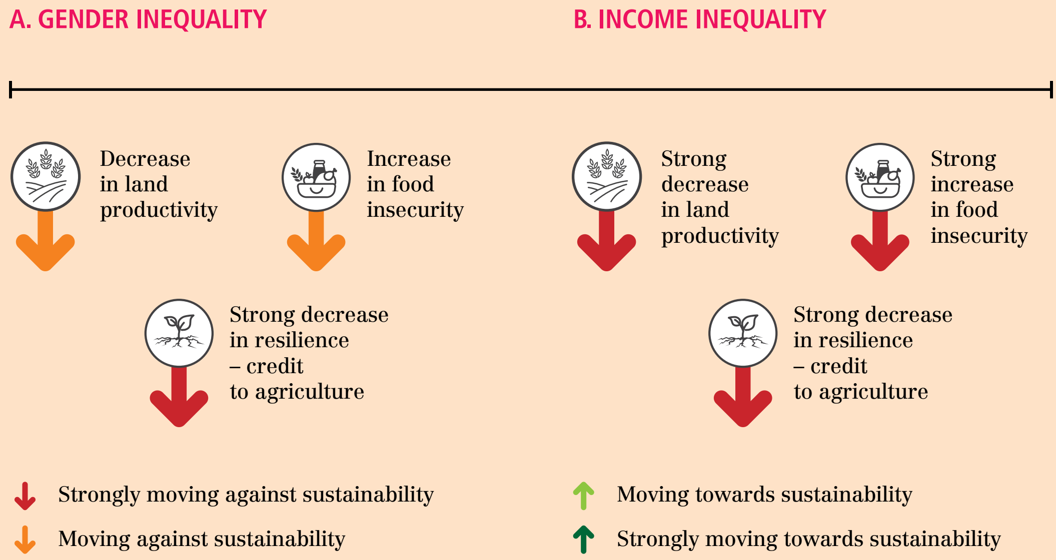
Agricultural sustainability requires increasing land productivity and reducing poverty and hunger; however, high levels of inequality can hinder progress towards these goals. Inequality is a result of one or more forms of discrimination against groups of people within a population. The many ways in which inequality manifests in a country undermines social cohesion, exacerbates the challenges of poverty and hunger, and limits the capacity of a country to achieve the SDGs.

The PROSA Global Analysis identifies strong empirical and conceptual relationships between sustainability in agriculture and economic and gender-based inequality. Income inequality is measured by the Gini index, while gender inequality is measured by the UNDP Gender Inequality Index (GII). The results indicate that higher levels of gender and income inequality coincide with reduced sustainability in agriculture across both social and economic indicators, including lower access to credit in agriculture, lower land productivity, and higher food insecurity. While several other factors may collectively influence the sustainability of agriculture, addressing these inequalities can contribute to an agricultural sector that is more productive, resilient and meets the food needs of the population.

The distribution of wealth in a society influences the productivity of its agricultural sector

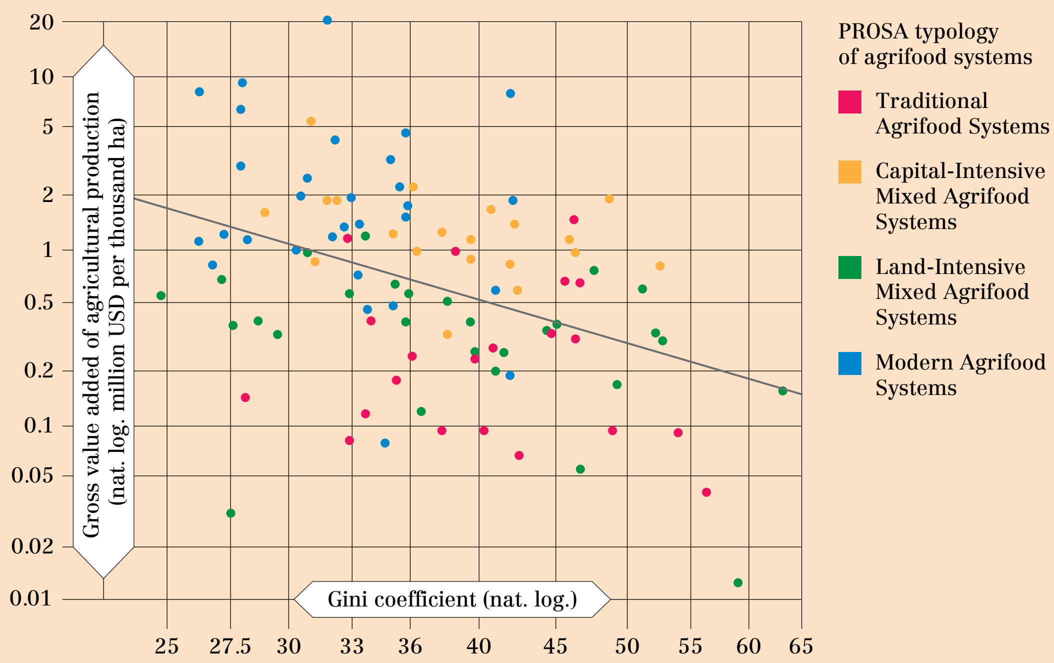
Globally, there is a clear negative relationship between income inequality and agricultural productivity across all agrifood systems typologies (Figure 12). Countries where incomes are highly unequal have, on average, lower levels of land productivity. The underlying mechanisms behind this relationship are diverse and often interrelated. Understanding these mechanisms is key for designing inequality-reducing actions that will stimulate agricultural productivity sustainably, especially in countries within Mixed Land Intensive and Traditional Agrifood Systems, where productivity gains are lagging.

FIGURE 11 **Directions of progress between gender and income inequalities, and key indicators of agricultural sustainability**



Source: Authors' own elaboration.

FIGURE 12 **Countries with greater income inequality are less productive in agriculture (2010–2016 average)**



Source: Authors' own elaboration of data from FAO (2019b) and the World Bank (2019b).

In highly unequal countries, most of the farming population lacks the economic resources and capacity to invest in appropriate agricultural technologies, as well as the knowledge to implement improved agricultural practices. This has direct consequences on the abilities of farmers to invest in their farms to make them more productive. As a result, inequality can contribute to a self-reinforcing poverty trap, in which low agricultural productivity levels contribute to lower incomes and food security, and further undermine farmers' ability to make the investments needed to improve productivity and incomes (Barrett and Carter, 2013).

High levels of inequality can also hinder agricultural productivity by influencing the distribution of reasonably priced agricultural credit. In unequal societies, large shares of the population lack viable assets to use as collateral to access formal agricultural credit arrangements (Ng'eno *et al.*, 2011). Agricultural credit is critical for farmers to manage the seasonality of agricultural income and expenditures, and to invest in technologies and long-term farming improvements. Without collateral to access formal credit, most farmers must forego agricultural credit entirely, or turn to higher-priced informal credit arrangements. Both situations act as a drag on average agricultural productivity and contribute to the deepening of economic inequalities.

Low agricultural productivity in economically unequal societies may also result from an unequal distribution of fundamental agricultural resources, such as land. In countries where a large percentage of the population derives a livelihood from agriculture, income inequality is highly correlated with inequality in land size of holdings (Berry, 1989). In these countries, when most of the available agricultural land is held by a minority of large landowners, productivity is generally lower than in places where land sizes are more evenly distributed. The large holdings tend to rely on low-paid and temporary labour, which may involve higher supervision costs and lower incentives for labourers to produce efficiently. By contrast, in countries where relatively smaller and more evenly distributed landholding size dominate, the use of family labour is more widespread, leading to lower supervision costs and higher incentives to produce efficiently. The literature estimates that globally, a reduction in the Gini Coefficient of landholding size (a measure of inequality in landholding) by one standard deviation is associated with an 8.5 percent increase in agricultural productivity (Vollrath, 2007).

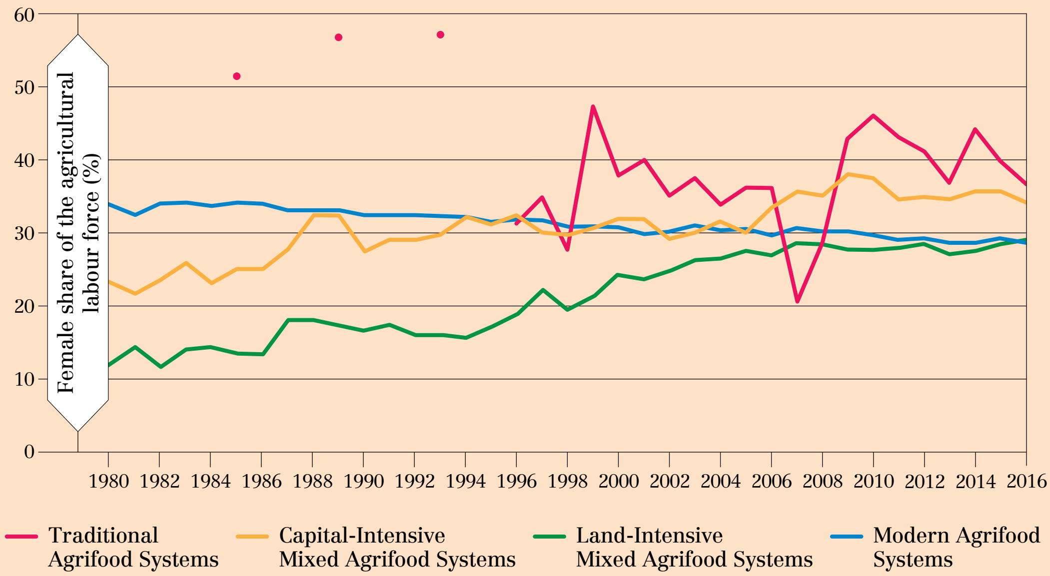
Agriculture is more productive in countries with greater gender equality

Achieving greater gender equality in all facets of economic and political life is fundamental to achieve progress toward sustainable agriculture. There is an urgent need to recognize women's role as key actors in the agriculture sector, and to address structural barriers that may hinder their capacity to contribute to land productivity. With the shifting gender dynamics in agriculture, women are making up a large, and growing, share of the agricultural workforce in many countries. Data from FAOSTAT shows that women's share of employment in agriculture has been increasing since 1980 in all country groups, except the Modern Agrifood Systems group (Figure 13). Ensuring gender equality is essential to increase agricultural productivity and sustainability.

Gender inequality undermines progress toward sustainable agricultural across multiple dimensions. The PROSA Global Analysis confirms that higher gender inequality[3] corresponds to lower land productivity, lower access to agricultural credit, and higher food insecurity (Figure 14). The pathways by which gender inequalities undermine these multiple dimensions of sustainable agriculture are diverse, context-specific, and often interconnected.

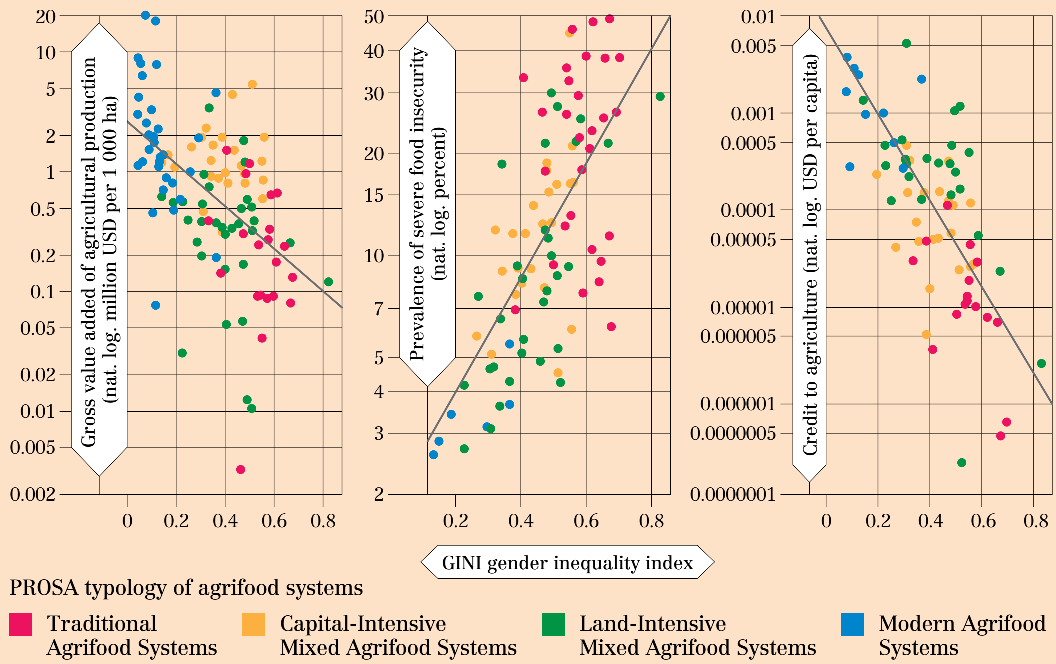
3 The GII measures assesses gender inequalities in terms of: (i) reproductive health; (ii) empowerment; and (iii) economic status. Reproductive health is measured by maternal mortality ratio and adolescent birth rates. Empowerment is measured by the proportion of parliamentary seats occupied by females and the proportion of adult females and males aged 25 years and above with at least some secondary education. Economic status is expressed as labour market participation, and is measured by the labour force participation rate of female and male populations aged 15 years and above.

FIGURE 13 Female participation to agriculture is increasing in countries within Traditional and Mixed Agrifood Systems (1980 to 2016)



Source: Authors' own elaboration of data from FAO (2019b).

FIGURE 14 Countries with higher gender inequality have lower land productivity, less access to credit, and higher food insecurity (2010–2016 average)



Notes: Credit to agriculture includes agriculture, forestry and fishing. Per capita is measured in terms of rural population. Food insecurity is measured using the FAOSTAT indicator prevalence of undernourishment (three-year average).

Source: Authors' own elaboration of data from FAO (2019b), World Bank (2019b) and UNDP (2019).

Fundamental structural barriers that limit women's access to and control over productive resources, their opportunities for advancement in work and education, and their ability to benefit from agricultural-sector support services, such as extension systems and subsidy programmes, undermines the sustainability of agriculture (FAO, 2011). For example, in many agricultural societies, gender inequality manifests in terms of weaker and less secure land rights, compared to men (Agarwal, 2012; FAO, 2011; Peterman *et al.*, 2011; Sitko, 2010). This makes female farmers more vulnerable to dispossession and less willing to invest in the long-term sustainability of their farms. Moreover, it undermines their ability to make necessary investments, because land is the primary source of collateral used to access most formal agricultural lending. Policies requiring joint titling of land between men and women have been successful at increasing gender equality in land ownership and empowering women (see Case study 2).

Due to the numerous structural barriers to economic and political participation that women face in many parts of the world, female farmers are typically less productive than their male counterparts (Quisumbing, 1996). Yet, women are efficient in making use of the resources they have (Quisumbing, 1996). When women farmers' access to resources is equal to that of men, the observed gender gap in productivity disappears. For example, in a study on Burkina Faso, Kenya and Zambia found that if women had the same access to capital and inputs as male farmers, agricultural output in those countries would increase by between 10 and 20 percent (World Bank, 2005). Addressing the missed potential of women in agriculture is critical in progress towards sustainable agriculture.

Public investments and service delivery tailored to marginalized groups increases productivity in agriculture

Investments in public goods and programmes that benefit marginalized populations is an effective strategy to reduce inequality and fostering a more productive and sustainable agriculture. These public goods include rural infrastructure, education and health services and programmes such as credit, subsidized inputs, information and extension. Ensuring that the benefits reach groups facing greater social and economic obstacles will require tailored services and targeted delivery.

Improving agricultural service delivery through more gender-sensitive and pro-poor targeting is one important mechanism to address inequalities in the agricultural sector. In the United Republic of Tanzania, for example, the Farmers' Groups Network developed a Farmer-to-Farmer extension model, to enhance communication and solidarity between male and female farmers. This model brings together farmers' groups of women and men, links them to extension officers, and facilitates dialogue around the gender-specific needs of farmers and the shared challenges affecting both men and women farmers (Mbo'o-Tchouawou and Colverson, 2014). This helps to overcome part of the traditional weakness in agricultural extension systems, which often fail to meet the needs of women farmers whose interests in and capacities to adopt new agricultural management practices are frequently different than those of men (Quisumbing and Pandolfelli, 2010). Through innovative strategies that identify and explicitly address the needs of marginalized farmers, inequalities can be reduced, leading to increased land productivity and thus a more productive and sustainable agriculture.

CASE STUDY 2 Improving gender inequality through inclusive land formalization in Peru

Throughout much of the world, inequalities in access to, ownership of and control over land persist for smallholders. Secure land rights increase the ability of farmers to make long-term investments in their land and to access credit, making them a critical element of sustainable agriculture (FAO, 2016b). However, due to weak governance of tenure, insecure and informal land ownership is common (FAO, 2012). When secure land tenure does exist, it is often gender-biased (RRI, 2017). Programmes intended to secure land titles for smallholders can reinforce existing inequalities between the sexes by formalizing unequal property rights. Women play an increasingly important role in agriculture, and ensuring their equal rights to land is a necessary step to increase female decision-making power and status within the household, protect against disinheritance, and reduce gender inequality (FAO, 2011).

Many countries have made efforts to introduce gender-equitable land tenure. However, success has been limited, due to difficulties in enforcement and implementation (Wiig, 2013). The Special Land Titling and Cadastre Project (PETT) in Peru is an example of a successful strategy to enhance women's rights to formal land titles through a mandatory joint titling requirement. In 1996, Peru enacted the PETT to facilitate rural land titling, using a specialized institution of Peru's Ministry of Agriculture. The new policy redistributed land between the sexes, by requiring that a man and a woman who share their life and cohabitate jointly title their parcel. Over the next decade, more than 1.5 million plots were registered, 57 percent of which were jointly titled (Wiig, 2012). From 2000 to 2004, the percent of jointly owned parcels increased from 13 percent to 43 percent, revealing a significant increase in joint titling during the project period (Deere and Leon, 2001; Fuentes and Wiig, 2009).

A number of factors contributed to the success of the PETT in promoting joint land ownership between men and women. A supportive legal system provided clarity on complex issues, such as how jointly owned land is administered in cases of divorce, death, inheritance and use as collateral. This was complemented with a successful campaign to provide all Peruvians with legal personal identification documents, which for the first time provided several women with the legal documentation required to register land. Finally, the joint titling component of the PETT was consistent with local cultural norms, which facilitated its acceptance. For instance, in Peru, there are few cultural taboos against women assuming male responsibilities, such as migrating to work elsewhere (Wiig, 2012).

As a result of the policy, women in communities where land parcels are jointly titled were found to be significantly more involved in agricultural decision-making than women in communities where no individual titling has taken place (Wiig, 2012; Wiig, 2013). The programme also contributed to improved economic empowerment for women, as women with joint land titles were more likely to be able to obtain credit than those without a title. The PETT programme provides a blueprint that other countries may follow to make progress toward greater gender equity in agriculture.

Sources: Deere and Leon, 2001; FAO, 2011; FAO, 2012; FAO, 2016; Fuentes and Wiig, 2009; RRI, 2017; Katz, 1999; Wiig, 2013; Wiig, 2012.

5 Farm size structure

KEY MESSAGES

- Larger and more mechanized farms are more profitable, due to advantages in economies of scale and a greater ability to take risks.
- Supporting diversification on large farms can improve long-term environmental and economic sustainability.
- Small, diversified farms can generate valuable environmental services and economic resilience; however, they often encounter the challenge of low levels of profitability.
- Improving the economic sustainability of small farms requires enhancing their access to scale-appropriate mechanization and supporting the inclusion of more profitable crops in their diversified systems. Addressing constraints is necessary and requires a mix of interventions, including development of markets, risk management tools and quality control schemes.

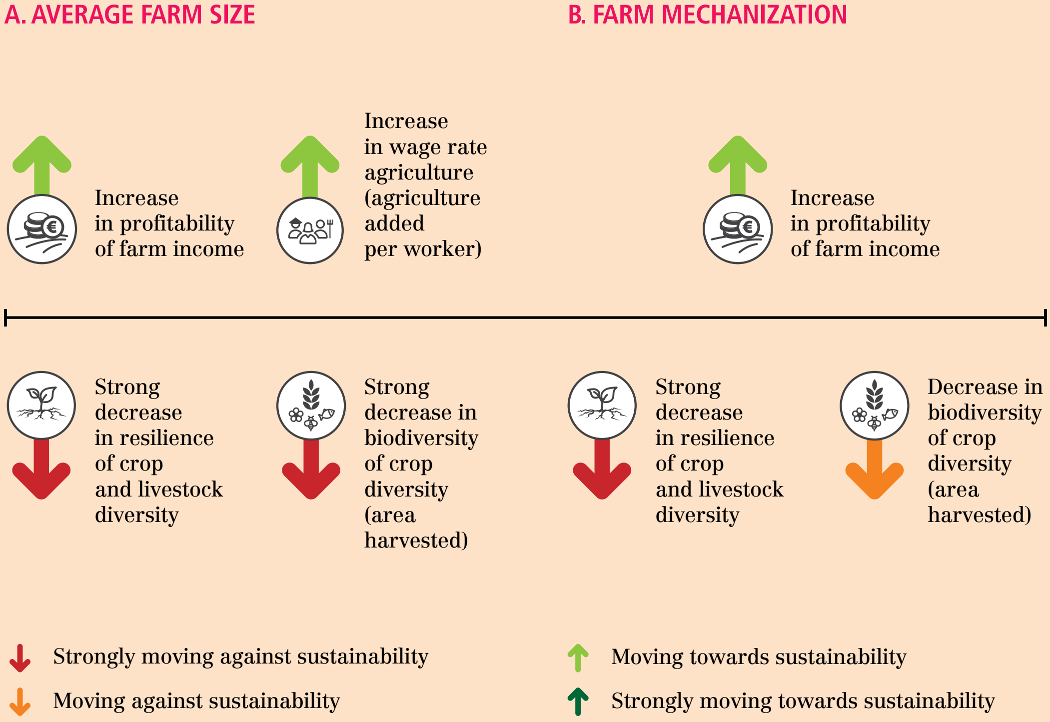
Average farm size and the levels of farm mechanization have important implications for the economic, social and environmental dimensions of sustainable agriculture. The size and level of mechanization of a farm influences its productivity, profitability and environmental impact, through factors such as the technologies and inputs that farms of different sizes apply, and the choices of crops grown. Moreover, the distribution of farm sizes within a country has important implications for the relationship between agricultural sector growth and poverty reduction (Jayne *et al.*, 2003).

There are 570 million farms in the world, of which 84 percent are less than 2 hectares in size and only 6 percent are larger than 5 hectares (Lowder, Skoet and Raney, 2016). Average global farm sizes show divergent trends between country groups. Between 1970 and 2010, farm sizes in countries within Traditional and Mixed Capital-Intensive Agrifood Systems have generally declined, due to growing rural populations, particularly in land-constrained countries. Countries within Modern Agrifood Systems experienced the opposite trend of rising farm sizes, which began in the 1990s, while the size of farms within Mixed Land Intensive Agrifood Systems has remained stable.

Dynamics in average farm sizes and farm size distributions involve complex trade-offs, for instance between the per-capita profitability of larger, more commercialized farms, and the land-use efficiency and diversity of smaller-sized farms. Generally, larger farms generate higher financial returns per unit of farm labour, by capturing efficiencies generated through economies of scale and production specialization, which are often linked to greater use of mechanized equipment. Smaller farms, on the other hand, typically draw heavily from family labour and, on average, generate greater output per unit of area farmed, albeit with relatively low productivity per worker (among many, see Berry and Cline, 1979; Feder, 1985; Schultz, 1964). Due to a wide range of production- and market-related risks and limited formal mechanisms to manage them, smaller-scale farmers often diversify their farm systems (and non-farm livelihood activities) to help spread these risks over a relatively higher number of production activities, compared to farmers with larger holdings (Rosenzweig, 1988; Pingali and Rosegrant, 1995; Barrett, Reardon and Webb, 2001).

Results from the PROSA Global Analysis highlight the trade-offs between the biodiversity benefits of smaller farms and the economic advantages of larger, more mechanized farms (Figure 15). Smaller, less mechanized farms are associated with greater resilience and biodiversity in agriculture, in terms of crop and livestock species. Higher farm profitability and wages, measured as agriculture value added per worker, on the other hand, are linked to larger average farms and higher levels of mechanization. Unpacking these relationships is important, given the increasing pressure on small-scale farmers to adapt to rapidly globalizing agrifood systems. Understanding the different ways in which farm structure impacts sustainable agriculture will help decision-makers when considering how to best support farmers in their countries.

FIGURE 15 Directions of progress between farm mechanization and average farm size, and key indicators of agricultural sustainability

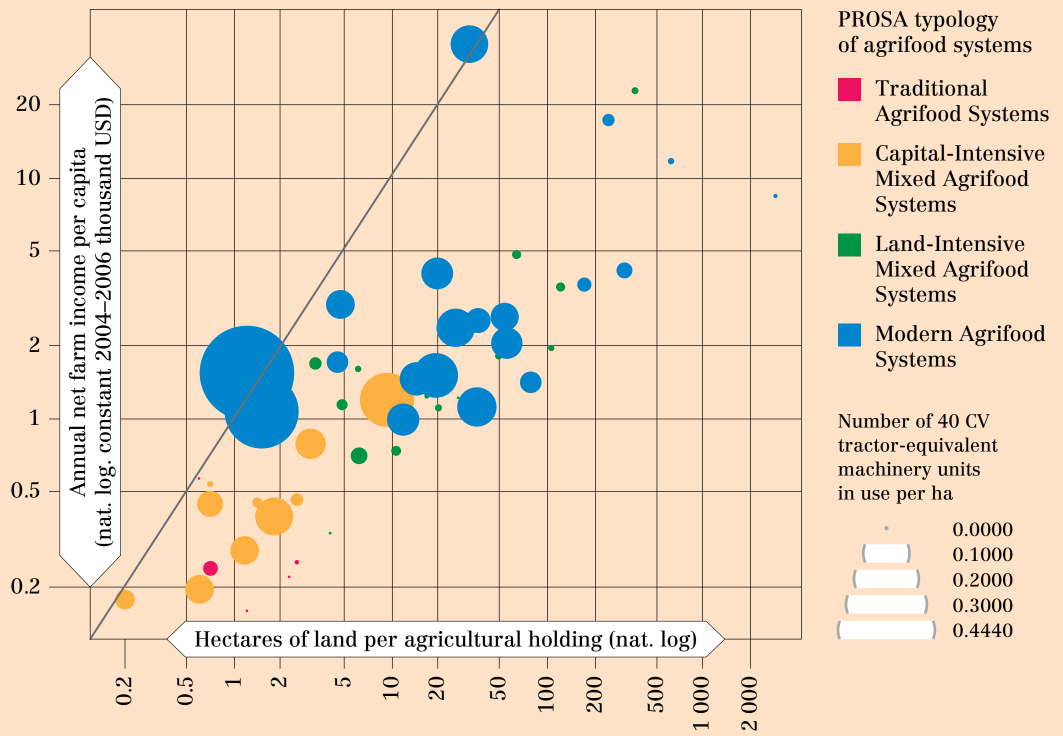


Source: Authors' own elaboration.

Larger and more mechanized farms are generally more profitable

The results of the PROSA Global Analysis highlight, globally, a strong relationship between farm size and mechanization, and net farm income per capita and agriculture value added per worker, a proxy of agricultural wages. As average farm sizes increase in a country, the net income per capita of people engaged in agriculture and levels of machinery use also increase (Figure 16). Trends show a dramatic increase in farm profitability and agriculture value added per worker in countries within Modern Agrifood Systems over the last six decades, as farms in these countries became more mechanized than those in any other group.

FIGURE 16 Net farm income per capita is higher in larger and more mechanized farms (2010–2016 average)



Source: Authors' own elaboration of data from FAO (2019b) and Lowder and Bertini (2017).

Farmers with large landholdings often specialize their agricultural production and orient it toward commercial markets (Von Braun, 1995; Timmer, 1997). Larger farms benefit more from specialization than smaller farms, due to the increasing returns to scale associated with specialization along the value chain (White and Irwin, 1972; Pingali and Rosegrant, 1995). For example, specialized large-scale farms benefit from input and machinery supply chains that are tailored to their needs, such as crop-specific machinery that allow a single operator to manage large land areas and high output volumes (White and Irwin, 1972). These advances in mechanization on larger farms require less farm labour, leading to higher farm output and wages per worker. However, in labour-abundant countries within Mixed and Traditional Agrifood Systems, mechanization can displace rural populations that primarily rely on agriculture for jobs, if off-farm employment opportunities are still limited (Pingali, 2007).

Downstream, larger farms enjoy lower per-unit costs of marketing and storage, and typically face lower transaction costs in meeting the quality, size and delivery standards required to modernize agrifood systems (Pingali, Khwaja and Meijer, 2005). At the production level, larger farms tend to better integrate into agricultural information networks (such as private and public extension systems) than smaller farms, and have a greater capacity to apply new information and technologies to improve farm profitability (Collier and Dercon, 2014). Furthermore, farmers operating larger landholdings often seek out specialized training and skills to improve their management and marketing efficiency (Chavas, 2001).

Larger farms are also more profitable because of their greater ability to access and utilize formal instruments to manage production and marketing risks, such as insurance and agricultural credit. This is because larger farms tend to be better capitalized and better able to meet the collateral requirements of commercial banks than small farms (Binswanger and Sillers, 1983). As a result, they are in a better position to pursue potentially risky, but profit-maximizing, farm management options than smaller farms. They can also better internalize the risk of experimentation with new technologies and practices, and allocate a portion of their land to test plots (Collier and Dercon, 2014). This sort of experimentation and risk-taking is much more constrained for small farms. Smaller farms, especially within Mixed and Traditional Agrifood Systems, are generally more risk-averse, due to resource constraints and the importance of their production to household food security. Under these conditions, smaller-scale farmers typically select a more diversified set of agricultural activities that minimize food insecurity, but often at the cost of greater profitability (Engels, Diulgheroff and Alvarez, 2014).

In many countries within the Traditional Agrifood Systems and some within Mixed Capital-Intensive Agrifood Systems, farm sizes are declining, due to rising rural populations on limited agricultural land and few employment opportunities in the non-farm economy (Lowder and Bertini, 2017; Masters *et al.*, 2013). Until population growth stabilizes and off-farm economy is able to absorb more labour (discussed in more detail in Section 3), farms in these countries are likely to stay small. This means that farmers in those countries most dependent on agriculture for income are those that have the smallest and least profitable farms. Addressing constraints faced by small farms on adopting practices and technologies that enable them to improve their profitability and reduce their risks is critical to achieve a more sustainable agriculture. This may include improving access to financial mechanisms to help improve risk management, linking them to low-cost agricultural service providers, and supporting the adoption of more profitable crops into their diversified cropping systems.

Smaller farms tend to have more resilient and biodiverse farming systems

The PROSA Global Analysis shows an inverse relationship between farm size and levels of crop diversification at a global level[4] (Figure 17). As average farm sizes decline, net profitability decreases. However, the diversity of crops grown increases (Klasen *et al.*, 2016). This relationship indicates potential positive benefits associated with small farms, in terms of more biodiverse, environmentally friendly, and resilient farming systems. Trends support this relationship, finding that in the last two decades, countries within Mixed Capital-Intensive and Traditional Aagrifood Systems (which tend to be associated with smaller farm sizes) have the highest crop and livestock diversity, in terms of production. However, Modern and Land Intensive Agrifood Systems, generally with larger farms, have experienced decreasing crop and livestock diversification in terms of area harvested since the 1960s. For Modern Agrifood Systems, the issue is increasingly urgent, as crop and livestock diversification have decreased both in terms of the value of production and the area harvested in the last several decades. This leaves farmers increasingly exposed to both natural and market fluctuations. Capturing the potential benefits of diversified systems requires effective policies that incentivize diversified production, along with risk management tools and investments to ensure that small and diverse farms are also profitable and food-secure.

Diversified production systems can generate benefits that cut across the economic, social and environmental dimensions of sustainability. For example, diversification enables farmers to improve the resilience of their livelihoods to a wide range of agricultural hazards, such as pest infestations, abnormal weather conditions and market volatility (Maggio, Sitko and Ignaciuk, 2018; Lin, 2011). Moreover, diversified farm systems typically provide a greater range of above- and below-ground habitats for increased biodiversity, require fewer

4 While global data on farm-level diversity does not exist, sector-level diversity is measured in the analysis, under the assumption that high sector-level diversity is driven at least in part by high farm-level diversity.

chemical inputs to manage disease and pests, and can improve soil health through differential nutrient uptake and atmospheric nitrogen fixation, thus leading to better environmental outcomes compared to less diversified systems (King and Hofmockel, 2016; Krupinsky *et al.*, 2002; Lin, 2011). Finally, in terms of consumption, greater crop and livestock diversity have positive impacts on dietary diversity and nutritional outcomes, when crops are grown for household consumption (Box 5) (Pellegrini and Tasciotti, 2014).

The vast majority of global farmland under large-scale and less diverse farming operations is associated with important environmental and economic concerns. Initiatives to support greater diversification of large-scale farming operations are important for the future sustainability of global agriculture. One strategy to consider is supporting markets for small grain cover crops, such as rye, barley and oats. These, in combination with legume cover crops, can be effectively integrated into large-scale farming operations. Using short grain cover crops, large-scale farmers can maintain consistent soil cover, thus improving soil health and reducing soil disturbance and erosions (Kaspar, Radke and Laflen, 2001). At the same time, these cover crops can reduce herbicide requirements and improve the efficiency of inorganic fertilizers (Reeves, 1994). This can have important benefits for the long-term productivity, and environmental impact of large-scale crop farming operations. Consumers of food and agricultural products have also a key role to play: given that large farms orient their production towards consumer markets, changes in consumer behaviour and associate development of markets are necessary.

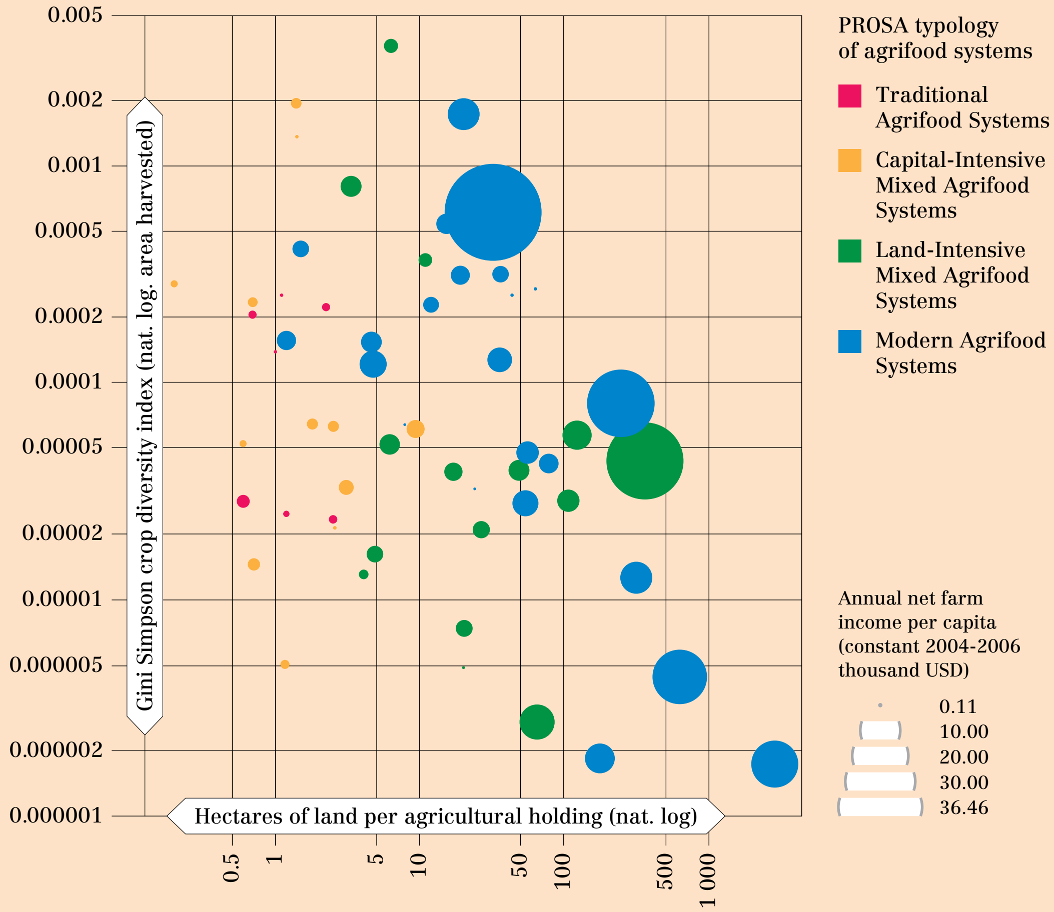
Small, diversified farms can make sustainable profit gains with adequate access to mechanization and by adopting higher-value crops

Smaller farms can maintain the positive environmental outcomes provided by diversified production systems while increasing profitability, through improved access to appropriate mechanization and adoption of higher-value crops and livestock in their cropping systems. Scale- and context-appropriate mechanization has the potential to improve the profitability and overall efficiency of smaller farms, especially in countries where labour costs are rising (Ratolojanahary, 2016). With rapidly increasing demand for high-value food products, well-designed diversification strategies integrating more remunerative food products, along with soil-enhancing crop, trees and livestock systems, can contribute to improving farm incomes while building long-term soil productivity (Hazell *et al.*, 2007; Hazell, 2011).

Smallholders face serious impediments to increasing the level of mechanization of their farms, often because of the small size of the holdings. The range of equipment tailored for smaller-scale contexts or alternative practices, such as no-till agriculture, is expanding but remains narrow (Friedrich and Kienzle, 2007; Lindwall and Sonntag, 2010). The limited value of small landholdings makes them unattractive as a collateral. Tractor service providers and equipment rental services are emergent strategies to improve access to low-cost mechanization options in small-scale farming communities. These innovative business models are supported by the proliferation of mobile-phone-based banking services and apps, which help link farmers to service providers. In Ghana, for example, the tractor-sharing smartphone application TROTRO Tractor helps farmers connect to tractor owners, to carry out land preparation activities (Case study 3). Through such services, small farms may be able to improve their overall labour productivity and enhance farm profitability.

Smaller farms can also increase their profits by integrating remunerative cash crops and nitrogen-fixing grain legumes into their cropping systems. Cash crops offer farmers the opportunity to increase their incomes through integration into commercially oriented supply chains, while incorporating legumes into small-scale systems can help increase farm profits, and, simultaneously, improve soil health and fertility.

FIGURE 17 Crop diversity, measured at the national level, decreases as farm size increases (2010–2016 average)



Source: Authors' own elaboration of data from Lowder and Bertini (2017) and FAO (2019b).

However, risks associated with global price swings, and challenges with meeting quality and consistency standards are significant barriers to entry to cash crop markets for many small-scale farmers (Dolan and Humphrey, 2000; Baffes, 2005). Furthermore, legumes are often thinly traded, which reduces market opportunities, and accessing seed can be a challenge. Addressing constraints on the adoption of diversified cropping systems that integrate legumes and cash crops with food crops can help enhance the profitability and long-term sustainability of small farms. This requires development of, and providing access to, markets for inputs and outputs, formal risk management tools, and quality-improving schemes (including training, extension services and investments).

It is critical to support smaller farms on a path to an agriculture that is more economically sustainable (Lowder, Skoet and Raney, 2016). While the mix of necessary actions will be country-specific, strategies aimed at promoting and removing constraints on sustainable intensification – including small-scale mechanization and incorporation of profitable crops in the farming system – offers some opportunities. This will be especially crucial in Traditional and Mixed Capital Intensive Agrifood Systems countries where farmers face the lowest incomes and levels of mechanization, and are the most reliant on agriculture for their livelihoods.

BOX 5 Diversifying production to improve household nutrition

Agriculture and nutrition are fundamentally linked, and agriculture has great potential to improve nutritional outcomes through the production of healthy and diverse foods. Studies on crop diversification have long focused on their economic and environmental impacts. More recently, there has been mounting evidence that crop diversification can also contribute to improved nutrition outcomes through better diets (Powell *et al.*, 2015; . Farmers that consume a portion of their own production can enhance their nutrition by increasing the availability of a greater variety of self-produced foods. Moreover, the more stable incomes generated through diversified systems can enable farmers to purchase healthy foods when needed. The inclusion of nutrient-dense and lucrative crops, and small-scale animal husbandry, in the production systems are key to both improving nutrition outcomes and increasing household incomes (FAO, 2015).

Approximately 2 billion people worldwide experience moderate or severe food insecurity. They are forced to compromise on the quality and quantity of their food, and are at increased risk of deficiency in vitamins and minerals as well as undernutrition. Increasing economic and physical access to diverse and nutritious foods for these populations is crucial (FAO *et al.*, 2019). This is especially the case for farmers in Traditional Food Systems countries who typically subsist on starch-based staple crops. Their diets often lack fruit, vegetables and animal products containing micronutrients that are vital for human growth and cognitive functions (Ruel, 2003). Yet, in many countries, agricultural sectors have been heavily tilting towards the production of staples and cash crops, resulting in a lack of knowledge, skills and infrastructure for effective production and delivery of locally available diversified food crops. The transition towards a more sustainable development path should include supporting more diverse and nutritious food systems. Integrated and multisectoral approaches to encouraging the production, harvesting, storage and processing of a diverse range of foods are a key element in achieving improved diets that contribute to better nutritional outcomes.

Sources: Demeke *et al.*, 2013; Ecker, 2018; FAO, 2015; FAO *et al.*, 2018; Hirvonen and Hoddinott, 2017; Kumar, Harris and Rawat, 2015; Makate *et al.*, 2016; Mango *et al.*, 2018; Mazunda, Kankwamba and Pauw, 2015; Powell *et al.*, 2015; Ruel, 2003.

BOX 6 Protecting global agrobiodiversity through legislation on plant genetic resources for food and agriculture

Around the world, farming systems are becoming more homogenous – both in terms of crop and livestock species, and of genetic diversity within species. This loss of biodiversity in agricultural production (agrobiodiversity) has significant negative impacts on the economic and environmental resilience of agricultural systems (see Section 2.3 of this publication). Policies and treaties encouraging the conservation of agrobiodiversity can drive positive changes in the resiliency of agriculture systems.

▸▸

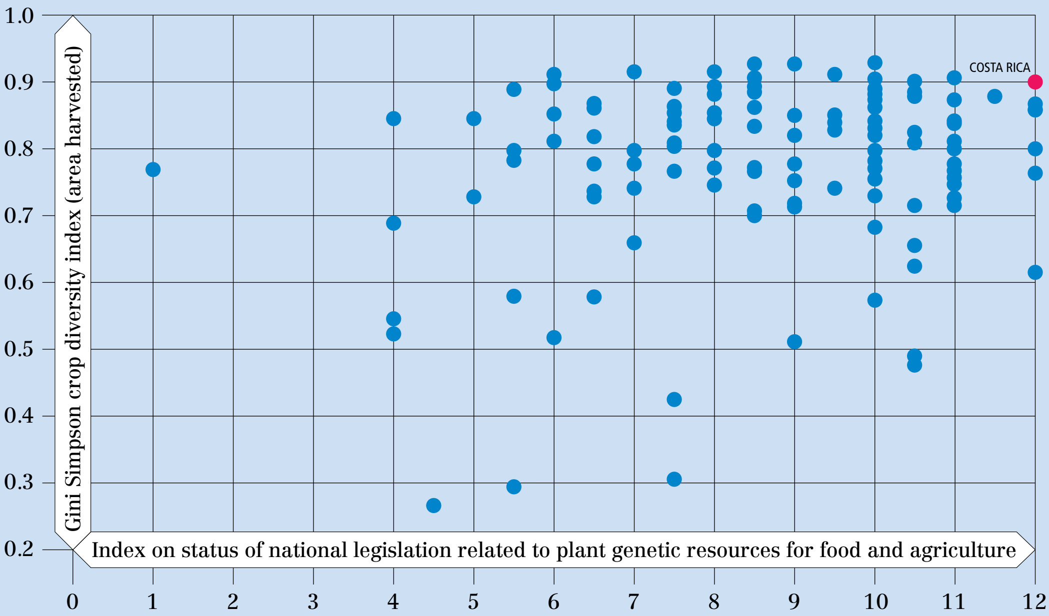
BOX 6 (cont.) **Protecting global agrobiodiversity through legislation on plant genetic resources for food and agriculture**

FAO monitors the status of Member Countries with regard to the enactment of national laws and signing or ratification of international agreements related to the conservation and use of plant genetic resources for food and agriculture. The status is communicated through the Report on the State of the World's Plant Genetic Resources for Food and Agriculture (FAO, 1997; FAO, 2010). According to FAO, Costa Rica, along with several other countries, has signed or ratified the greatest number international agreements and national laws relating to the conservation and use of agricultural biodiversity (including access to plant genetic resources and seeds), plant protection, intellectual property rights, and biosafety (FAO, 2010).

Costa Rica is a pioneer in protecting its rich natural resources, including biodiversity in agriculture. The Government of Costa Rica was the first to pass legislation in 1996 creating a programme of payments for ecosystem services, which includes rewarding farmers for protecting biodiversity. In 2010, the Government listed agrobiodiversity as a strategic area within the climate change and environmental management pillar of the State Policy for the Agricultural Sector and Rural Development (OECD, 2017).

Costa Rica's progress towards the conservation of agrobiodiversity is reflected in its high crop species diversity. In the PROSA Global Analysis, Costa Rica ranks as one of the most crop-diverse countries (Figure 18). Although further strengthening of national capacities to implement the countries' commitments to agrobiodiversity conservation is needed, Costa Rica is on the right track towards ensuring the protection of plant diversity in agriculture.

FIGURE 18 **Costa Rica has both high crop diversity and a high status in terms of national legislation on plant genetic resources for food and agriculture (2014–2016 average)**



Sources: FAO, 1997; FAO, 2010; OECD, 2017.

CASE STUDY 3 Sustainable mechanization in Ghana: the role of farmer-to-farmer tractor hiring services

Ghana is experiencing a surge in mechanization among smallholder farmers. Mechanization has the potential to increase farm profitability while maintaining the environmental resilience of small farms, when adapted to smaller-scale, diversified systems. Yet, the vast majority of small-scale farmers in Africa continue to rely on hand hoes and animal traction to prepare their fields. In Ghana, however, it is estimated that 44.3 percent of small-scale farmers (cultivating 12 acres or less) use tractors (Chapoto, Houssou and Cossar, 2014). A growing and successful farmer-to-farmer service hiring market is playing a key role in the relatively widespread use of tractors.

One of the few countries in Africa within Mixed Capital-Intensive Food Systems, Ghana is undergoing economic and social transformations that are altering the structure of agriculture in the country. The World Bank estimates that between 2001 and 2017, per capita gross national income has increased by more than 500 percent in Ghana (World Development Indicators data portal). Over the same period, the Ghanaian population shifted from being mostly rural to mostly urban (World Development Indicators data portal). Ghana's economic growth is pulling people out of rural areas into more remunerative urban employment, and putting upward pressure on agricultural wage rates (Jedwab, 2011). These changes helped drive rapid growth in relatively larger farms, along with demand for agricultural mechanization (Diao *et al.*, 2018; Jayne *et al.*, 2016; Chapoto *et al.*, 2014).

While increasing land size and labour costs create incentives for farmer to replace manual farm labour with tractors, most Ghanaian farmers lack the economic resources to purchase a tractor. To meet the growing demand for tractors, the Government of Ghana intervened. In 2007, the Government began importing new tractors and established subsidized Agricultural Mechanization Service Centres (AMSECs), one of four initiatives of the country's agricultural development strategy. The Government provided highly subsidized loans for tractors to the AMSECs, which in turn provided mechanized services to farmers. However, the initiative had limited success due to problems concerning profitability and the maintenance of tractors (Benin, 2015; Houssou *et al.*, 2013).

At the same time, a private-sector-led market for tractor services was developing. A growing population of medium- and large-scale farmers in Ghana are buying used tractors imported through private businesses, and are using these tractors to cultivate their own fields while also providing mechanized services to other farmers (Diao *et al.*, 2014; Chapoto, Houssou and Cossar, 2014). Hiring out tractor services, when combined with personal use, has made it worthwhile for many medium- and large-scale farmers to purchase tractors, and has expanded the use of tractors among smallholders that cannot afford one themselves (Diao *et al.*, 2014). The process is being facilitated by the emergence of start-up companies, such as TROTRO Tractor, which helps farmers connect to nearby tractor owners via a smartphone application. This technology has the potential to increase access to tractors for smallholders with no connection to hiring services, and to expand provider networks.

▸▸

Learning from the example of Ghana, governments in countries with similarly growing demands for small-scale agricultural mechanization can help stimulate markets when necessary, while encouraging the development of a private-sector machinery supply chain. These measures can be implemented in parallel to investment in research and development for tractors and implements that are adapted to local conditions and smaller-scale contexts.

Sources: Benin, 2015; Chapoto *et al.*, 2014; Diao *et al.*, 2018; Diao *et al.*, 2014; Houssou *et al.*, 2013; Jayne *et al.*, 2016; Jedwab, 2011.

6 Global integration of agriculture

KEY MESSAGES

- FDI in agriculture creates opportunities to increase economic resilience in agricultural systems, through incentives for diversification and improved access to credit for agriculture.
- Supporting the adoption of integrated pest management approaches in diverse export-oriented agricultural systems can enhance the sustainability of global integration.
- Without complementary policies to ensure that local farmers and firms participate on equal footing with foreign investors, an influx of FDI may contribute to reduced resilience and increased inequality.
- Investments that adhere to the Principles for Responsible Investment in Agriculture and Food Systems can ensure that processes of global integration contribute positively to food security.

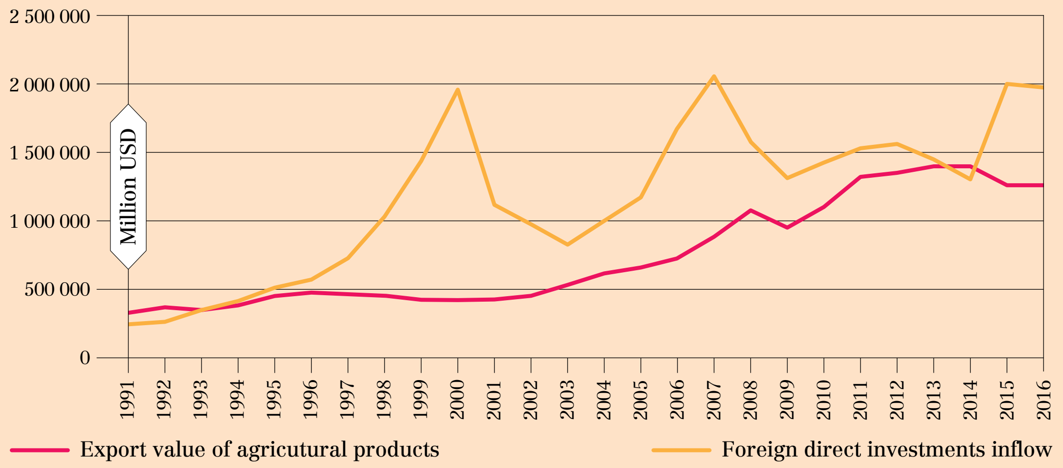
Agricultural and agrifood systems have long been globally integrated through trade. However, as a result of rapid technological, dietary, financial and regulatory transformations, the pace of global integration of agriculture has increased remarkably. FAO estimates that between 1991 and 2016, global inflows of FDI into the food and agriculture sector have increased sevenfold in real terms, reaching almost USD 2 trillion. Over the same period, the value of agricultural exports has tripled and now exceeds USD 1.2 trillion globally (Figure 19).

The rapid global integration of agriculture through FDI and trade can contribute to important beneficial changes in agricultural sectors. For example, FDI in agriculture creates opportunities for transfers of knowledge and technologies to make agriculture more productive and markets more efficient (Oman *et al.*, 1989; Reddy, 2005; Rama, 1999). Moreover, it can enable access to new and more remunerative markets for farmers, while providing consumers with a wider range of food products at lower costs than ever before (Reardon, Timmer and Berdegue, 2004; Dolan and Humphrey, 2000).

However, increased global integration can also leave many behind and may be accompanied by adverse environmental consequences that undermine sustainability. When countries seek to attract FDI in agriculture without implementing policies to support local farmers and small companies, well-capitalized foreign agribusinesses can squeeze out local actors and create conditions for uncompetitive market practices to flourish (Rugman, 1975; Connor, 2003; Coe and Hess, 2005; Caves, 1996). Moreover, competition between countries to attract foreign investments and to access foreign agricultural markets may contribute to a "race to the bottom", through a loosening of labour and environmental policies (Olney, 2013; Dewit, Görg and Montagna, 2009; Levinson, 2003).

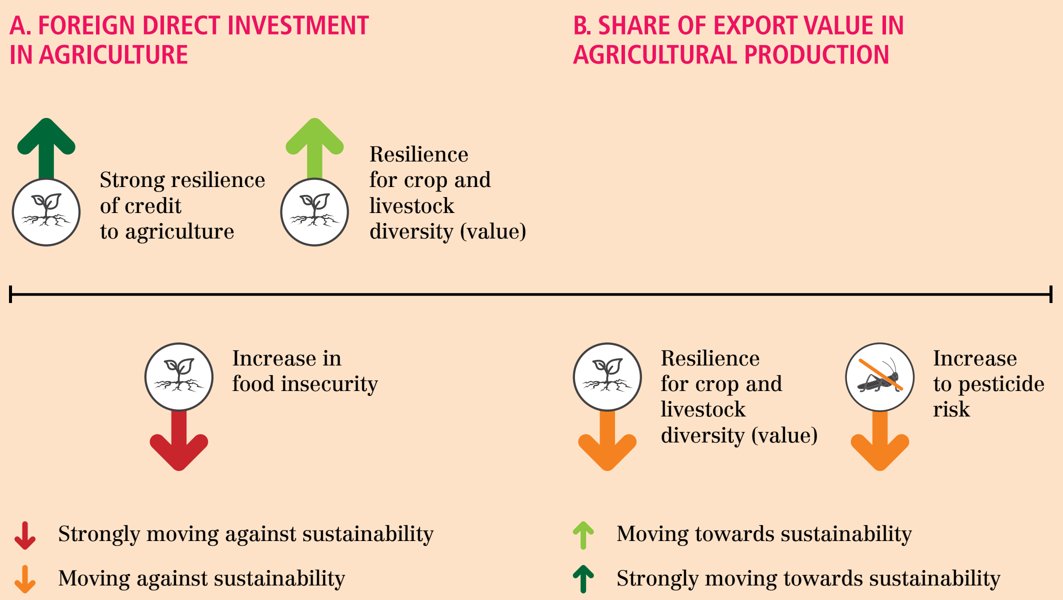
The results of the PROSA Global Analysis highlight the important trade-offs between the global integration of agricultural, environmental, social and economic sustainability (Figure 20). Higher FDI in agriculture is associated with greater economic resilience in agriculture, in terms of both credit to agriculture and crop and livestock species diversity (measured by production value). Results indicate, however, that FDI is also associated with greater national-level food insecurity. More worrisome relationships are found between higher export orientation of agricultural goods and environmental indicators, including elevated use of pesticides and lower crop and livestock diversity. Containing these trade-offs will require national strategies and responsible private investment that prioritize the inclusion of local farmers and minimize environmental costs.

FIGURE 19 FDI inflows into agriculture and agricultural exports are increasing globally (1991–2016)



Source: FAO, 2019b.

FIGURE 20 Directions of progress between FDI in agriculture and the share of export value in agricultural production, and key indicators of agricultural sustainability



Source: Authors' own elaboration.

Foreign direct investment in agriculture create opportunities for agricultural diversification

With appropriate polices in place, FDI in the agriculture sector can support more economically and environmentally resilient agrifood systems, by incentivizing crop and livestock diversification. The PROSA Global Analysis highlights a strong positive relationship between FDI inflows into agriculture and levels of diversification of crop production. Through diversification, at both a household and a national level, risks associated with production variability (tied to pests or climate stresses) and market price variability can be reduced by spreading these risks over a wide range of crops. Highly diverse cropping systems can help enhance soil health, improve biodiversity on agricultural lands, and mitigate the impact of agricultural pests. However, capturing these benefits depends fundamentally how diversification is achieved and managed.

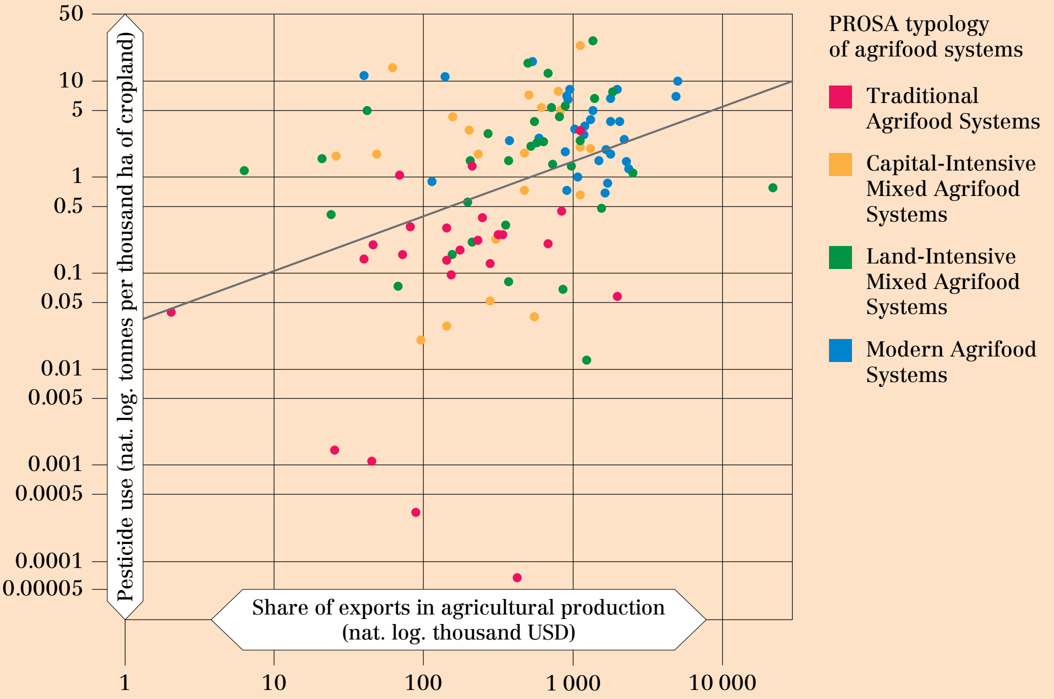
Crop diversification in response to FDI inflows can occur along multiple pathways. For example, through investments in downstream segments of agricultural supply chains, such as processing and intermediation, FDI can support the creation of new agricultural markets for farmers and thus incentivize farmers to produce new, and often more remunerative, crops (Reardon, 2015). FDI inflows targeting agricultural land, which increased sustainably following the global food and fuel price spikes in 2007–2008, often seek to boost the production of crops destined for export or crops to serve as inputs into emergent markets, such as biofuels (Schoneveld, German and Nutakor, 2010; Borras *et al.*, 2011). This pathway can contribute to increased levels of diversification at a national level, but may also entail a range of social and environmental risks associated with the displacement of small-scale farmers and agricultural expansion into previously uncultivated regions. In many countries within Traditional Agrifood Systems and some countries within Mixed Agrifood Systems, FDI often directly targets small farmers, to support the production of traditional and non-traditional export crops through input supply contracts and the provision of downstream market linkages (Poulton, Dorward and Kydd, 2010). This enables diversification of small farms, often through a shift away from locally traded and consumed food crops (Rama and Wilkinson, 2008; Gwynne, 2006).

The different pathways by which FDI can influence diversification will require context-specific policies to ensure that outcomes are consistent with the principles of sustainable agriculture. Yet, fundamentally, it is important to ensure that FDI in agriculture does not create new risks and burdens for marginalized populations and fragile ecosystems. For example, in places targeted by FDI for large-scale land acquisitions, the land rights of local farmers must be well protected, to guard against displacement. Where FDI incentivizes farmers to shift toward export-oriented cash crops, it is essential to establish price floors and social safety net systems to ensure farmers do not bear the brunt of global price drops. Finally, where FDI is flowing into downstream segments of the agrifood systems, financial mechanisms to support the competitiveness of local, small-scale processors and traders can help to prevent oligopolistic market structures from taking hold.

Pesticide use is on the rise and managing the risks of overuse and misuse in export-oriented agricultural systems is critical for sustainability

The excessive or erroneous use of agrochemicals is of significant concern to sustainable agriculture, as it can lead to poisoning of farmers, degradation of soil, and contamination of water and food supplies. Since the 1990s, global pesticide use has increased by 38 percent, with particularly large increases in both countries within Mixed Land and Capital Intensive Agrifood Systems. The PROSA Global Analysis shows that there is a strong positive relationship between higher levels of agricultural export orientation and pesticide use (Figure 21). Effective policies and regulatory frameworks to capture the economic benefits associated with agricultural exports, while minimizing the downside risks of high use levels of agro-chemicals such as pesticides, can help ensure that the global integration of agrifood systems through exports is sustainable.

FIGURE 21 **Higher levels of agricultural export orientation are associated with increased use of pesticides (2010–2016 average)**

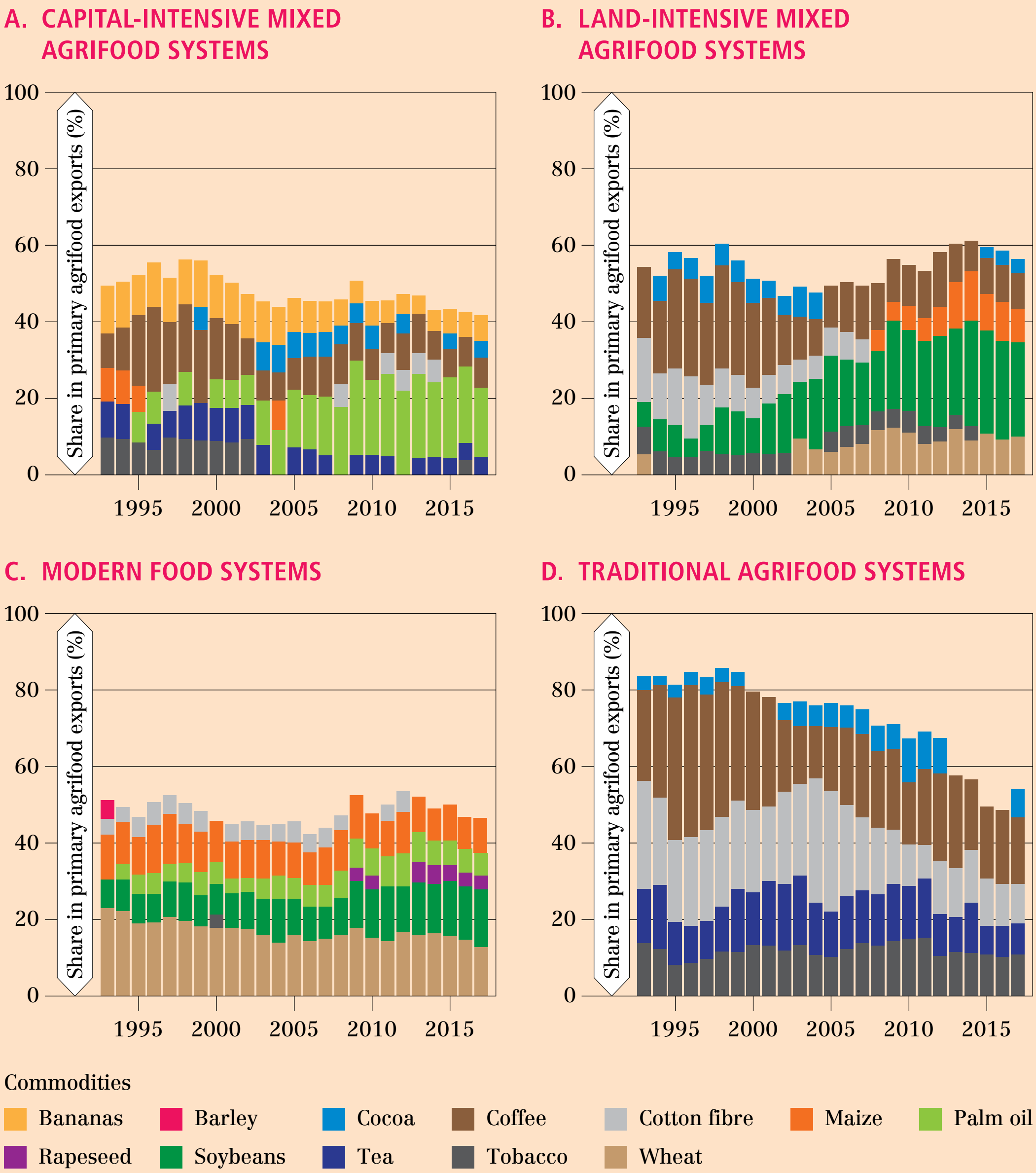


Source: Authors' own elaboration of data from FAO (2019b).

The relationship between pesticide use and levels of agricultural exports is driven in large part by the nature of export-oriented agricultural production systems and their predominant crops (Longo and York, 2008; Dinham, 2003; Matthews, Wiles and Baleguel, 2003; Thrupp, 1990; Weir and Schapiro, 1981). As shown in Figure 22, in countries within Traditional Agrifood Systems, exports are dominated by traditional export crops: cotton, coffee, tea, tobacco and cocoa. Although countries within Traditional Agrifood Systems have consistently low average levels of pesticide use, export crops grown in these agrifood systems typically require more intensive use of pesticides than food crops grown for local consumption. Moreover, due to their higher value and quality demands from importing markets, farmer often have greater incentives to apply pesticides to their export crops than to crops destined for local markets.

In the other country groups, exports are driven by food and fuel crops that are typically grown in large-scale conventional production systems, including maize, wheat, soybean, banana and palm oil. For example, exports of maize, soybean and wheat in countries within Mixed Land Intensive Agrifood Systems have increased, from less than 10 percent of total primary exports in the early 1990s to over 43 percent in 2016. This has been driven by the rapid expansion of large-scale farming systems in these countries, where production often occurs in monocrop or simple two-crop rotation systems (Jorgenson, 2005). These large-scale conventional systems are often equally or more pesticide-intensive as the high-value traditional and non-traditional export crops that dominate exports from countries within Traditional Agrifood Systems (Murray, 1994).

FIGURE 22 A small number of export crops accounts for a large share of agricultural export value, in all production systems



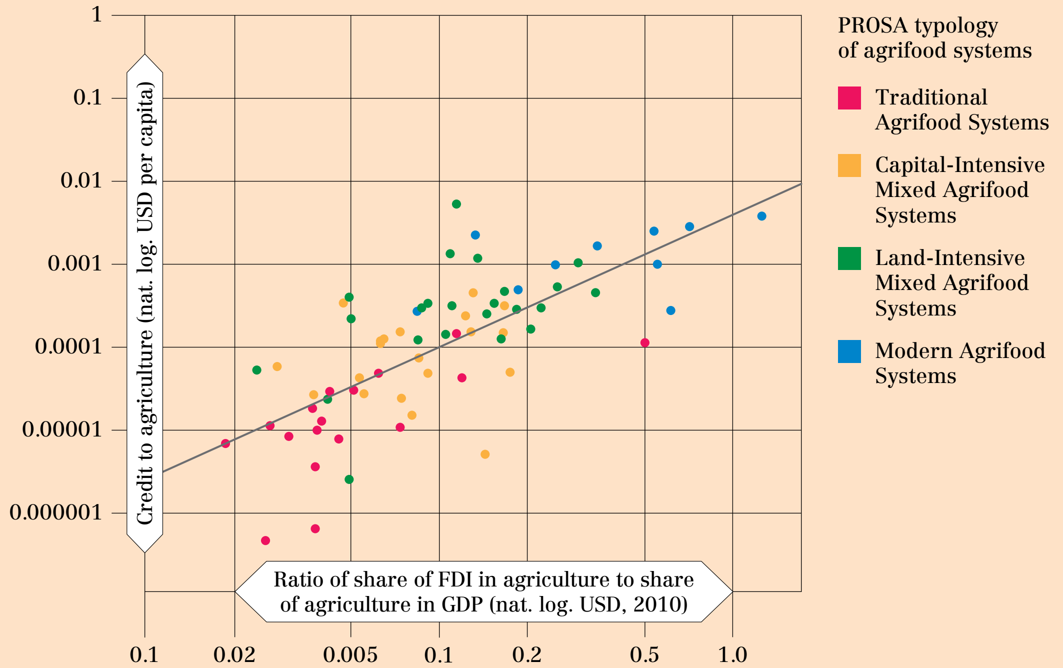
Source: Authors' own elaboration of data from FAO (2019b).

While exporting agricultural commodities is vital for the economies of many countries, and the livelihoods of millions of farmers, identifying strategies to reduce the need for pesticides and the risks of pesticide misuse and overuse in these systems is important for their sustainability. This requires a multidimensional approach. On one hand, regulatory systems must be in place to ensure that pesticides used in export agriculture meet global safety standards, that farmers are provided training and equipment for their proper use, and that disposal systems exist to minimize contamination of water and soil. On the other, farmers require support to adopt integrated pest management systems, which reduce reliance on chemical pesticides. This will entail investments in appropriate research and extension services, to ensure that farmers have the right knowledge and tools to manage pests in an integrated way, as well as markets that incentivize their adoption through price premiums.

Foreign direct investment in agriculture can support farmers' access to credit; ensuring firms offer credit in a competitive and equitable way is vital

Due to the seasonal nature of agricultural incomes and expenditures, and exposure to shocks, mechanisms to increase resilience are important for farmers. Agricultural credit can help farmers to maintain relatively smooth consumption levels throughout the year despite seasonal fluctuations in income; purchase needed inputs such as seeds and fertilizer; and make capital investments to enhance the long-term production capacity of their farms. Creating conditions for farmers to access agricultural financing at reasonable interest rates and on competitive and equitable terms is therefore essential to support a more sustainable agriculture. This is especially crucial for capital constrained countries within Traditional Agrifood Systems, where credit to farmers is extremely low with little increase over time.

FIGURE 23 **Credit to agriculture is positively associated with FDI inflows into agriculture (2010–2016 average)**



Note: agriculture includes agriculture, forestry and fishing. Per capita is measured by rural population.

Source: Authors' own elaboration of FDI data using FAO (2019b).

The PROSA Global Analysis shows that increases in agricultural FDI are associated with increased credit to agriculture (Figure 23). The mechanisms underlying this relationship are diverse and occur at all levels of agricultural value chains. One particularly important source of credit associated with FDI in agriculture is the provision of commodity-specific input financing to farmers, mainly tied output contracts or outgrower arrangements (Poulton, Dorward and Kydd, 2010; Adjognon, Liverpool-Tasie and Reardon, 2017; Reardon, 2015). Under these arrangements, firms provide farmers with in-kind credit for seeds and other inputs at relatively low interest rates. Farmers are then typically obligated to repay their loans in kind, with agricultural commodities. Such arrangements are particularly attractive to resource-constrained farmers, who face high barriers to accessing other formal credit arrangements (Binswanger and Rosenzweig, 1986). Moreover, tied output arrangements are frequently bundled with extension services, to help farmers meet stringent quality and quantity standards.

However, these types of credit arrangements come with risks for farmers. Tied credit arrangements usually target export crops. As a result, the prices farmers receive for their output, and therefore their capacity to repay input credits, are subject to considerable volatility arising from fluctuations in global prices and exchange rates. Moreover, due to the power imbalance between farmers and firms, lending arrangements may be biased against farmers, locking them into deals in which they bear most of the risk associated with price and production volatility (Singh, 2002; Little and Watts, 1994; Key and Runsten, 1999). Finally, tied contract arrangements tend to target relatively better-off farmers, who are less likely to default and can comply with the quality and quantity requirements of the firms (Reardon, 2015). This can contribute to a deepening of economic inequalities in rural communities.

Effective policies and institutional frameworks are required to ensure that credit provided to farmers as part of foreign (and domestic) investments contribute positively to sustainable agriculture. This includes ensuring that the risks of loan default due to weather shock, pest and disease outbreak, market volatility, and other covariant risks are not borne primarily by farmers. The specific instruments required to reduce and share risks will vary by context. However, in general terms, the use of financial instruments that allow third-party actors – such as banks, investment firms and in some cases, public entities – to defray the risks for firms of lending to farmers can be effective. This may include, for example, a first loss guarantee mechanism. Strengthening the bargaining power of farmers is also critical. Commodity organizations and farmers' groups can serve as platforms for collective negotiations on contract and credit terms with firms, thus helping to balance the uneven power dynamics between firms and farmers.

Integrating small farms into the process of global integration can have positive effects on food security

The benefits of FDI for economic well-being and food security depend in large part on the inclusion of local smallholders. However, the results of the PROSA Global Analysis highlight a concerning relationship between FDI in agriculture and food security. Being attentive to the ways in which an influx of FDI can adversely affect food security is essential when developing strategies to ensure that FDI contributes to the progress toward sustainable agriculture.

Food security is a multidimensional concept and includes considerations of food availability, access and utilization. Despite the progress made in recent decades, food security remains a threat to sustainability, especially in countries within Traditional and Mixed Capital-Intensive Agrifood Systems. If not effectively managed, FDI in agriculture can adversely affect food security along multiple dimensions (Mihalache-O'Keef and Li, 2011). For example, FDI that targets the production of export-oriented crops can displace food crop production at a farm or regional level. This may adversely affect both local and household level food availability, as well as the access conditions resulting from changes in price ratios between export crops and food products (World Bank, 2005). Moreover, FDI in direct agricultural production through large-scale land acquisitions may limit access to, and the availability of, resources in agriculture such as land and water for local producers, thus jeopardizing their food production capacity (Hallam, 2011). Finally, FDI in agriculture is often disproportionately captured by a narrow group of relatively better-off farmers and other value chain actors, leading to an increase in economic inequality and a reduction in the agricultural growth elasticity of poverty reduction (Irz *et al.*, 2001). As a result, growth induced by FDI in agriculture may fail to pull large segments of the rural population out of poverty, with implications in terms of the food access capacity of those left behind.

However, where FDI in agriculture is well regulated by national governments and investors are accountable, it can increase the food security of local farmers in environmentally sustainable and socially equitable ways (see Case study 4). Practical guidance for both governments and investors to ensure that FDI in agriculture generates positive food security benefits can be found in the Principles for Responsible Investment in Agriculture and Food Systems developed by the Committee on World Food Security (CFS, 2014). The ten principles draw attention to the importance of inclusive, gender-sensitive and transparent investments in agriculture to achieving food security and long-term sustainability. Moreover, they highlight the diversity of roles and responsibilities that governments, businesses, civil society actors and the international community must play to ensure that investments in agriculture contribute positively to the three dimensions of sustainable agriculture.

CASE STUDY 4 Foreign direct investment and vertical collaboration in the Polish dairy sector

Amid the growing concern that the global integration of agrifood systems is forcing local small-scale farmers out of markets, the case of Poland's dairy sector shows how responsible foreign private investment can increase farmers' access to credit and enhance local food security.

Milk is an important agricultural product in Poland. As of 2017, Polish dairy farmers were responsible for 2 percent of total milk production globally (FAO, 2019b). Just wo decades before, however, the Polish dairy sector was characterized by low productivity and poor-quality milk. Without sufficient collateral, small-scale dairy farmers struggled to obtain low interest bank loans and invest in their production systems. In the 1990s, the country went through an economic transition process that included opening agriculture to foreign competition. Through a process of vertical coordination between foreign owned-dairy processing companies and local dairy farmers supplying milk, the share of high-quality milk produced in Poland rose from 30 percent to 80 percent between 1996 and 2001.

Poland's advanced economic reform strategy, supported by a stable political and institutional system, and cheap but relatively skilled labour force, has created attractive conditions for FDI inflows, including in agriculture. At the time, Poland's accession to the European Union helped create an enabling environment for FDI, by reinforcing the institutional and economic stability in the country and creating prospects for a large single market and economic growth. By 1999, FDI inflows into the Polish dairy sector had reached USD 23 million, and local dairy farmers were becoming integrated into the commercial dairy supply chain and were making improvements to their farms and the quality of their milk. At the milk production level, foreign-owned dairy processing companies provided supplying farmers with programmes on improving milk quality; credit for feed, on-farm cooling tanks and milking equipment; and co-signed for bank loans with preferential interest rates.

The assistance programmes had a significant effect on on-farm investments. A study of 280 dairies in northeast Poland showed that half of new investments were financed with loans. Domestic companies began adopting the supplier assistance model, and by 2001, the study showed little difference between farmer assistance programmes offered by foreign dairy processing companies versus domestically owned ones.

As a result, most small farms were not pushed out of the market, but continued supplying milk, and the quality of their milk improved. At the same time, domestic companies improved their supplier policies and the gap in high-quality milk delivered to domestic versus foreign dairy processing companies disappeared by 2000. These changes enabled domestic companies to comply with European Union quality standards and become more competitive on the international market.

Foreign direct investment and the globalization of agriculture can drive both positive and negative outcomes for sustainability. Ensuring that foreign investment inflows into agriculture are responsible and do not leave small-scale farmers behind is important for both private companies and governments. Foreign investment that collaborates with and supports local farmers, as practiced in the Polish dairy sector, can generate substantial benefits in terms of technology transfer and increased capacities of local farmers and firms.

Sources: Dries and Swinnen, 2004; FAO, 2019b.

7 Government support to agriculture

KEY MESSAGES

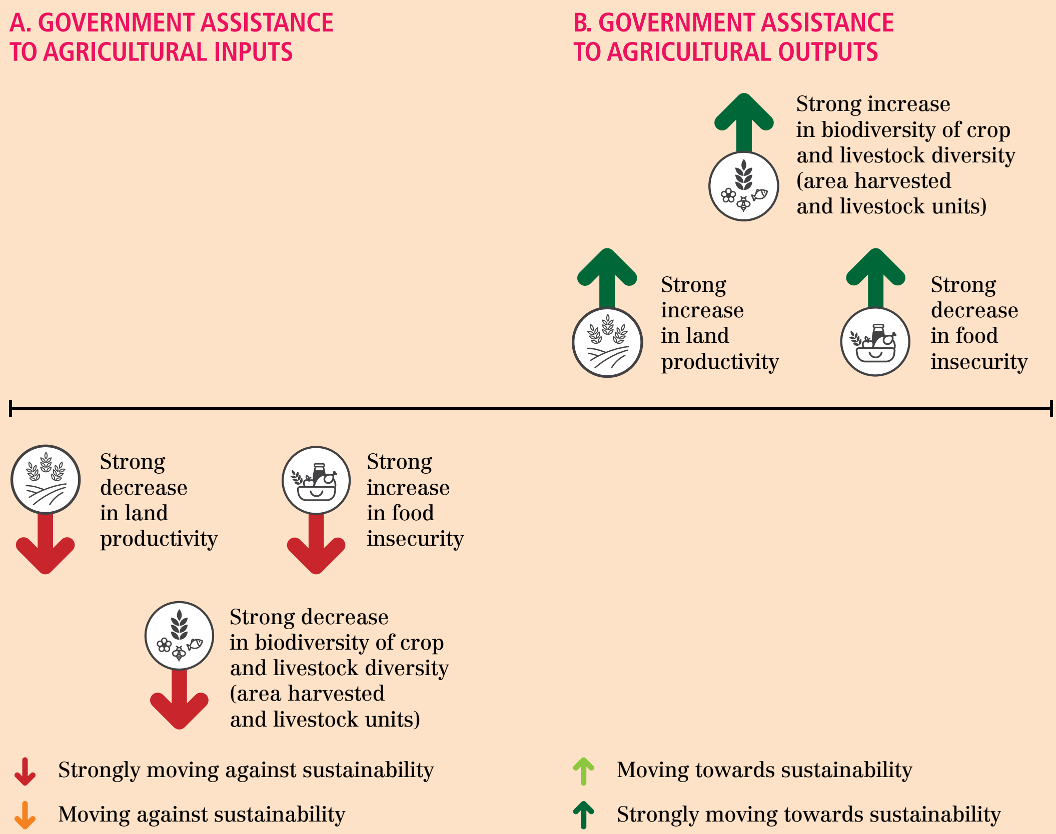
- Input subsidies may be an important policy instrument to stabilize agricultural producers' incomes in the short term; however, they may have limited effects on agricultural productivity in the longer term.
- Input subsidies tend to absorb substantial amounts of public resources, while having weak income transfer efficiency due to poor beneficiary targeting.
- Output support can have a more positive effect on sustainable agriculture by supporting markets for a diverse range of agricultural products; however, they also have weak income transfer efficiency and may require substantial public expenditures.
- Alternative, less distortive policy measures yield higher returns than support to input use or commodity outputs, in terms of agricultural productivity and sustainability. These include direct cash transfers to poor households and investments in public goods, such as research, knowledge transfer and infrastructure.

Across countries, governments support agriculture to achieve a diverse set of policy objectives. The range of applied policy measures is wide and the mechanisms through which they affect producers and consumers can be complex. Yet, their effectiveness in stimulating agricultural productivity and sustainability may be assessed using agricultural support indicators. This study focuses on the most common types of support provided to individual agricultural producers: support to commodity outputs and support to inputs used in agricultural production.[5]

The PROSA Global Analysis includes agricultural support indicators in an attempt to assess their empirical and conceptual relationship with indicators of agricultural sustainability (Figure 24). While the overall picture is not simple, and varies across country contexts, results indicate that globally, government assistance to agricultural inputs are associated with movement away from sustainability in agriculture, while assistance to farms' commodity outputs are associated with greater sustainability. The indicators measured cut across social, economic and environmental dimensions, and include land productivity, food insecurity and crop and livestock biodiversity.

5 Agricultural support indicators summarize the complex agricultural policy settings in a set of easy-to-interpret numbers that can be compared across countries and over time. They are now a well-established tool for monitoring and evaluating agricultural policies. Several initiatives are active in this area, including the work of FAO, the Islamic Development Bank (IDB), OECD and the World Bank. The World Bank research project on Distortions to Agricultural Incentives (Anderson and Nelgen, 2013) constitutes the most comprehensive agricultural support data set in terms of country coverage and length of time series. The indicators from this database, the NRA to farm outputs and input use, were used in the analysis, in combination with the FAOSTAT Agricultural Orientation Index. The NRAs used in this quantitative analysis do not capture other types of support, most importantly public expenditures on research and development, extension services and investments. Existing databases covering these expenditures are limited in country coverage, impeding inclusion of such data in the quantitative analysis; they were only analysed qualitatively.

FIGURE 24 Directions of progress between government assistance to inputs and outputs in agricultural production and key indicators of agricultural sustainability



Source: Authors' own elaboration.

Input support is globally concentrated among lower-income countries with traditional or mixed agricultural systems. They are often implemented to promote productivity growth among resource-constrained farmers and to improve national food security, typically for dominant staple foods. Low productivity levels and high food insecurity remain critical limiting factors to sustainability in many of these countries, especially those within Traditional Agrifood Systems. As such, these subsidies are being implemented under conditions where productivity levels are low by global standards and where food insecurity is widespread. In addition, the subsidies are focused on a narrow range of crops, which has implications for diversification levels. By contrast, output support is provided more often in modern agricultural systems, to support farmers' incomes and to ensure continuity in agricultural activities. These modern systems have high productivity levels by global standards and a low incidence of food insecurity.

Given that the choice between the various forms of support is often motivated by the overall structure and challenges faced within a country's agricultural sector, it is not possible to infer a causal relationship between a government's support to input or output markets and the sustainability indicators.[6] That said, the type of support provided and the way it is implemented has important effects on outcomes for sustainability.

6 Data constraints are also important. Although Anderson's database is the most comprehensive, it has many gaps, particularly on the coverage of support to agricultural input use.

Input subsidies should be time-bound, better tailored, and targeted to those in need

Subsidies to agricultural inputs are an attractive way for governments to support farmers: they seem relatively easy to implement compared to alternative policy instruments, and have an immediate effect on income stabilization in the short term by lowering input costs and boosting production. Many countries, particularly those within Mixed Agrifood Systems, allocate non-trivial amounts of public resources to input subsidies. Nevertheless, the long-term effects of input subsidies on the agricultural sector are much less clear-cut.

Measures aimed at improving access to and use of agricultural inputs range from price support for inputs (such as seeds, feed, fertilizer or pesticides), credit programmes and other measures to encourage investment in agricultural capital goods (for example, irrigation equipment and farm machinery), to on-farm services (veterinary services, technical assistance, etc.). Weak implementation design and poor targeting of input subsidies tend to most benefit those who are already engaged in input-intensive production activities. In particular, subsidies to the use of variable inputs, such as seeds or fertilizers, may have limited effects on raising productivity if they are not tailored and targeted to those in need (Brooks and Wiggins, 2010). Subsistence farmers may not be reached by input subsidies at all, although the marginal effects on land productivity are potentially highest in their cases (Ashra and Chakravarty, 2007; Lunduka, Ricker-Gilbert and Fisher, 2013). Findings from the PROSA Global Analysis show that at the global level, variable input subsidies coincide with higher food insecurity and have no relationship with fertilizer use. The lack of relationship between support to input use and fertilizer use suggests that those farmers who could benefit the most from the subsidies are either not receiving them, or are not using the inputs effectively.

A key implementation problem is whether the input subsidy ever reaches the rural households in need, due to poor design, leakages or diversion of fertilizers from government programmes to illegal markets. Syphoned coupons can be resold on an illegal secondary market to the same intended beneficiaries at close to market prices (Holden and Lunduka, 2010; Mason, Jayne and Mofya-Mukuka, 2013). In Malawi and Zambia, despite the overall positive effects on crop yields, an estimated 30 to 40 percent of fertilizer from government distribution programmes was diverted or resold before ever reaching farmers (Jayne and Rashid, 2013). Programme beneficiaries further this secondary market by reselling their coupons when they are not able to make efficient use of the input, or when there are difficulties in collecting the inputs. Even if intermediaries were to sell these syphoned input subsidies at a lower-than-market price, buyers are more likely to be from better-off households (Holden and Lunduka, 2010). The portion of subsidies that has not reached the beneficiaries represents an opportunity cost to public resources, and could be devoted to address other pressing needs of the agricultural sector.

Well-off households are also those that receive more coupons or subsidies directly from public programmes, which can undermine the development of markets for inputs. A "new wave" of fertilizer subsidy programmes in Africa attempts to address the crowding out of commercial distribution programmes by targeting those farmers that are least able to purchase fertilizer, but would benefit from increased use of it (Xu *et al.*, 2009). While these programmes target relatively poorer farmers in areas where demand for commercial fertilizers is low, they are not always effective. Evaluation studies show that male-headed households, households with larger farms, and wealthier households receive more fertilizer (Holden and Lunduka, 2010; Mason, Jayne and Mofya-Mukuka, 2013). These households are likely to have bought fertilizers independent of the subsidy, leading to no increase in overall fertilizer use. Furthermore, several studies show that farmers' use of fertilizer is driven by output prices rather than fertilizer prices (Rajapaksa and Karunagoda, 2009; Weerahewa, Kodithuwakku and Ariyawardana, 2010). As a result, the subsidies provided by the government may have minimal impact on overall fertilizer use and associated productivity, raising questions about the usefulness of the policy and the high costs associated with it.

Even if all input subsidies were to reach the right farmers, subsidy programmes may still not lead to higher yields, due to untimely delivery and low yield response. In Zambia, over 30 percent of households reported that fertilizers channelled through the national Fertilizer Support Programme were not delivered in time for planting (Xu *et al.*, 2009). The untimely application of fertilizers, often associated with delayed planting, leads to lower yields (Arslan *et al.*, 2015; Xu *et al.*, 2009). Furthermore, the efficient and effective use of fertilizer depends on the quality of soil. Soil degradation reduces crops' ability to use the nutrients from inorganic fertilizers, leading to overall reduced efficiency of fertilizer use, as observed in sub-Saharan Africa (Kanyamuka, 2018; Marenya and Barrett, 2009).

Finally, the evidence shows that with time, input subsidies tend to capitalize in prices of inputs, leading to increased government expenditures on maintaining the subsidy. This comes at the expense of other expenditures that are key for long-term agricultural productivity and sustainability, such as investments in productive public goods and social expenditures.

Input subsidies, if necessary, should be designed as a time-bound measure to increase access to inputs of those in need. So-called market-smart subsidies – delivered for example through targeted vouchers or matching grants – could be used to activate agricultural input markets by stimulating demand in private markets and lower the start-up costs of private distributors that are entering the input markets. However, in order to be effective, input subsidies must be part of a broader productivity enhancement strategy. Such a strategy should aim at improving both the input supply and farmers' demand. Input supply measures encompass elimination of duties and taxes, improvement of transport infrastructure, support of strategic public-private partnerships to establish regional procurement and distribution facilities, scaling up of input dealer networks, and financing of input suppliers. Strengthening demand for inputs requires not only provision of inputs, but also improving knowledge and skills of farmers, promoting availability and use of complementary practices such as irrigation and soil organic matter, and improving performance of product markets to increase prices and reduce risks (World Bank, 2008).

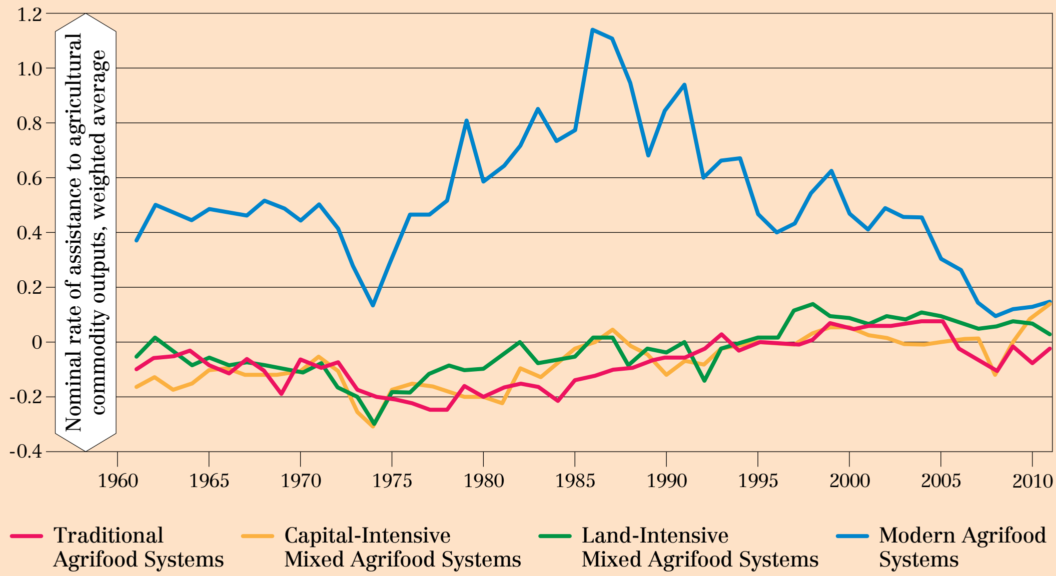
Output subsidies might have a better impact on sustainable agriculture than input support, if they target environmentally friendly practices including diversification; however, they also come at a high cost

Among the various production-oriented policy measures available to governments, output support can have a more positive effect on sustainable agricultural outcomes compared to input use measures, under specific conditions. Output-linked support tends to increase producer prices, and as such, enhances the incomes of beneficiaries. Depending on the particular policy instrument used, it may create incentives for farmers to invest in increased productivity. Subsidies that are targeted towards certain production practices – such as agricultural diversification in cases where the support encourages farmers to engage in a wider variety of production activities – may lead to greater environmental sustainability (Ashra and Chakravarty, 2007). Results from the PROSA Global Analysis are in line with this outcome, finding a positive relationship between output support and both crop and livestock species diversity. Yet, support linked to commodity production is one of the most distortive policy options, in terms of agricultural production and trade, and is often associated with high government expenditures. Moreover, it tends to increase environmental pressures due to the increased use of inputs and agricultural land expansion (Henderson and Lankoski,

2019) and may jeopardize other governments' efforts to protect the natural environment. The impact on food security will largely depend on whether the beneficiary households are net buyers or net sellers of the supported commodity (or commodities), as well as the effects on other commodity markets and whether consumer compensation programmes are in place.

Governments support agricultural outputs to achieve different objectives across countries. In countries within Modern Agrifood Systems, support to commodity production has been implemented to increase food availability in the post-World War II era, and later, to ensure decent farm incomes and to maintain agricultural production in areas that are less attractive for agricultural production. In countries within Traditional and Mixed Agrifood Systems, governments use commodity output support measures to meet two objectives. On one hand, they impose taxes on cash crops to ensure government revenue, particularly in those countries where other sources of revenue, such as income taxation, are more difficult to implement. On the other hand, they provide price incentives to the production of staples, to achieve national and household-level food security objectives. Additionally, governments may intervene in the agricultural sector by providing subsidies to agricultural commodity production. The average assistance provided to all outputs largely depends on the importance of cash and staple commodities in the overall basket of agricultural production in a given country, and the public resources available for subsidies. In the least developed countries, the average assistance tends to be close to zero or negative (Figure 25).

FIGURE 25 Nominal Rate of Assistance to outputs, weighted averages from 1961 to 2011



Source: Authors' own elaboration of data based on Anderson and Nelgen (2013).

However, supporting agricultural commodity production has distortive effects on commodity markets and results in misallocation of resources. The degree of distortedness depends on the choice of policy instrument. In developed countries, production subsidies may benefit agricultural producers, but impose an important burden on consumers, who face higher prices. They lead to excess supply and reduce global prices for agricultural commodities, negatively affecting farmers in developing countries that do not provide similar support, by lowering their incentives to invest in productivity growth (Dorward and Morrison, 2015;

McCulloch, Winters and Cirera, 2001). The European Union's price support for grains and milk prior to the reforms made in the early 2000s are typical examples, in which guaranteed prices for farmers led to overproduction that was marketed abroad. The excess supply on international markets, further stimulated by export subsidies, contributed to lowering international commodity prices, which adversely affected production in developing countries. Further, price incentives to staple goods in developing countries may have an opposite effect on the household welfare of the intended beneficiaries, if households are net consumers of supported commodities. By elevating food prices, these programmes may reduce access to food for consumers, many of whom are also farmers. In addition, price incentives have a relatively weak income transfer efficiency compared to other types of government support, such as direct payments, while also increasing environmental pressures. Increased use of agricultural inputs to produce more output may lead to unsustainable use of natural resources, including through the overuse of water, fertilizers, land degradation, nutrient run-off and water contamination, among others. It also creates incentives for monoculture (Van Winkle *et al.*, 2015). Globally, as the application rates of inorganic inputs increase to unsustainable levels, water quality worsens and food insecurity remains high, it is necessary to ensure that output subsidies support regenerative farming practices and positively impact food security.

Output support has potentially positive effects at national and global levels, for example when subsidies target specific crops or livestock, thereby increasing output diversification. This impact on agricultural diversity is found in the PROSA Global Analysis, where higher levels of crop and livestock diversity, in terms of area harvested and value of production, both coincide with higher levels of output-oriented assistance to agriculture. A common pattern of strongly market-oriented farming systems is their tendency to specialize in the production of standardized crop and livestock products. This usually coincides with the disappearance of traditional crops that are not as cost-efficient as competing high-yield varieties, thus increasing the dependency of individual farmers on a smaller number of income-generating activities and, ultimately, reducing biodiversity. Policy measures supporting the production of traditional and rare varieties of crops and animal breeds can give incentives to farmers to include, into their farming, activities that are otherwise not economically attractive. However, this can also be achieved using other policy instruments, which require production of a targeted commodity and are less production- and trade-distorting than blunt support to commodity outputs.

Investments in public goods and direct payments are better policy options for increasing agricultural productivity and sustainability in the long term

A more sustainable development path includes allocating scarce public resources to direct transfers to the intended households or investments in public goods, including research, infrastructure and human capital (health and education). While subsidy programmes for input use or commodity outputs can have positive effects on sustainability, such as higher farm wages and poverty reduction in farming households, their high cost often does not exceed their benefits (Jayne and Rashid, 2013; Morris *et al.*, 2007). Given that close to 70 percent of all government transfers to and from farmers are in the form of producer price supports (Box 7), decision-makers must weigh these high opportunity costs against other avenues of public support to agriculture (OECD, 2019).

Government investments in productive public goods have longer-term positive returns on agricultural productivity and sustainability. Investments in public goods address many of the root causes of low productivity and incomes in agriculture, with higher payoffs and more widespread benefits than subsidies (Donovan, 2004; Govereh *et al.*, 2006). For example, building roads can help rural farmers access markets, and improvements to public education can help develop farmers' capacities to adopt new agricultural technologies. These could be combined with direct payments to help the poorest households overcome short-term difficulties. For example, decoupled cash transfers to farming households may help boost their income, while avoiding the distortive effects on market incentives and leakages common in the traditional agricultural subsidies. This is because unlike output or input support measures, cash transfers to farm households are not tied to the production of a specific commodity and do not require complex distribution channels. A combination of such non-distortive short- and longer-term strategies is necessary to achieve productivity gains sustainably.

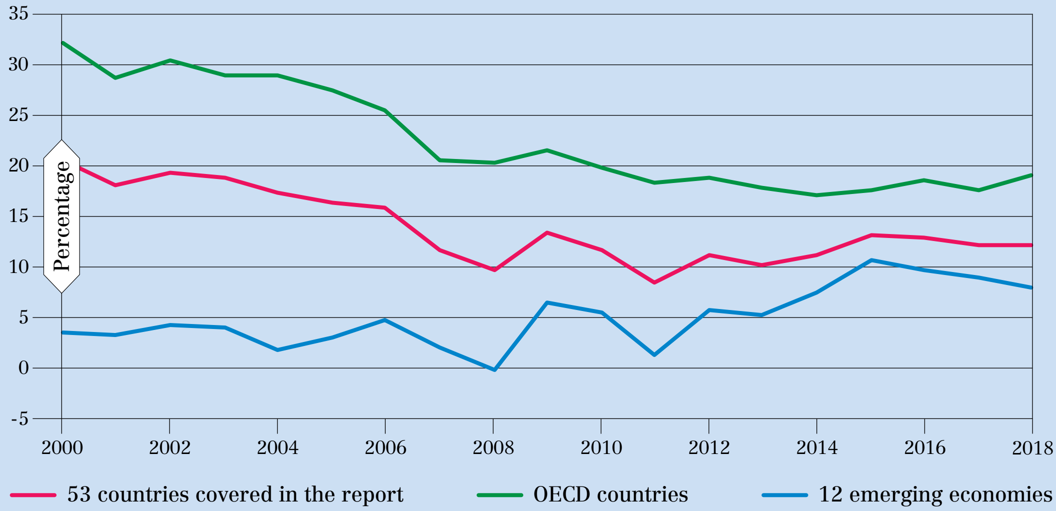
Ultimately, any intervention in the agricultural sector must be consistent with government policy efforts within the sector and across other sectors of the economy. In many countries, policy coherence is of concern and more coordination between various government institutions is needed, particularly on cross-cutting issues related to the environment, development and planning, and social affairs.

BOX 7 Government support in OECD countries and selected emerging economies

From 2016 to 2018, the agricultural policies applied in 53 countries1 provided approximately USD 528 billion worth of support per year to their agricultural sectors, according to the Organisation for Economic Cooperation and Development (OECD) report *Agricultural Policy Monitoring and Evaluation 2019* (OECD, 2019a). More than two thirds of this amount was spent on policies creating transfers to individual agricultural producers, while the rest was destined to the provision of general services to agriculture and to support consumers of agricultural goods.

The support to agricultural producers, measured through a Producer Support Estimate and expressed as a share of gross farm receipts for cross-country comparisons, has been declining in OECD countries for two decades. At the same time, it has been increasing in the 12 emerging economies covered by the report (OECD, 2019a). In recent years, the support provided has converged and followed similar, slightly declining trends, largely driven by market developments rather than policy reforms (Figure 26). However, recently, the support levels have started to diverge again.

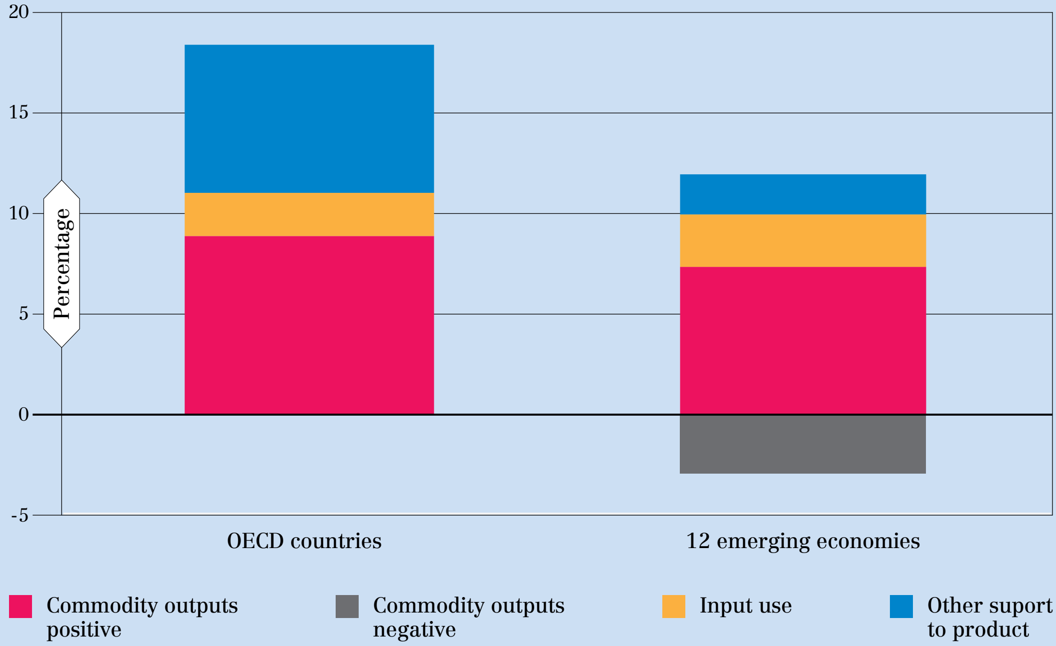
FIGURE 26 Evolution of the Producer Support Estimate, 2000 to 2018 (percentage of gross farm receipts)



Source: OECD, 2019b.

BOX 7 (cont.) Government support in OECD countries and selected emerging economies

FIGURE 27 Composition of support to agricultural producers, 2016 to 2018 average (percentage of gross farm receipts)



Source: OECD, 2019b.

In most of the 53 countries examined in the report, a large share of the policy transfers to individual producers are provided through support based on commodity outputs and input subsidies (OECD, 2019a; see Figure 27). These two types of support are highly production- and trade-distortive and act as disincentives to increasing productivity, sustainability and resilience. OECD recommends removing such support, to improve the functioning of domestic and international markets, reduce pressures on natural resources, and free up limited public funds. Redirecting the funds to provide transitional income support and invest in agricultural innovation, environmental protection and resilience would better strengthen agricultural productivity and sustainability.

Note: The countries covered include OECD Member countries, non-OECD European Union Member States and twelve emerging economies: Argentina, Brazil, China, Colombia, Costa Rica, India, Kazakhstan, the Philippines, the Russian Federation, South Africa, Ukraine and Viet Nam.

Source: OECD, 2019a.

8 Conclusions

This PROSA analysis has sought to shed light on the key factors that drive changes in the indicators that measure the sustainability of agriculture, at the country level. This paper, therefore, presents evidence-based insights into the key actions required to transition towards a more sustainable agricultural development pathway. Based on the analysis, five major driving forces that shape the sustainability indicators are identified: population dynamics, farm size structure, inequality, global integration, and government support. For each, depending on the decision maker's context, this paper identifies practical solutions to ensure that the interventions contribute positively towards sustainability.

The ways in which each driver affects the multiple dimensions of sustainability highlights the interconnections, synergies and trade-offs that must be managed in different global contexts to achieve agricultural sustainability. Achieving sustainability in agriculture cannot be seen in isolation from achieving overall sustainable development. Unless stressors that affect agricultural production are addressed, SDG target 2.4 is unlikely to be achieved by 2030. Many solutions, as discussed in this report, focus on addressing the socio-economic circumstances of rural populations. Therefore, policymakers should focus their efforts on creating a positive enabling environment for sustainable structural transformation, supported by strong anti-poverty measures. Simultaneously, they should also ensure actions against environmental degradation, and target increased efficiency in the use of natural resources.

Given the nature of agriculture, which is inherently bound with both the biophysical and social spheres, there is no single solution. What works for a land-abundant country may not be applicable to a country with limited land resources. However, there are a few exceptions. For instance, the fight against gender and income inequality is crucial across countries. In order to increase sustainability across social dimension.

Work on striving to understand both the sustainability criteria and the drivers behind them should continue. Currently, there is considerable heterogeneity in countries' starting positions along various dimensions of sustainability. However, the end goal is the same: ensuring that future generations enjoy access to productive, clean and healthy land that produces nutritious food for all.

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Annexes

Annex 1. List of countries by agrifood system group

TABLE A1 List of countries by agrifood system group

Country ISO3 code	Country name	Agrifood system group
AFG	Afghanistan	Traditional Agrifood Systems
ALB	Albania	Capital-Intensive Mixed Agrifood Systems
DZA	Algeria	Land-Intensive Mixed Agrifood Systems
AGO	Angola	Traditional Agrifood Systems
ARG	Argentina	Modern Agrifood Systems
ARM	Armenia	Land-Intensive Mixed Agrifood Systems
AUS	Australia	Modern Agrifood Systems
AUT	Austria	Modern Agrifood Systems
AZE	Azerbaijan	Capital-Intensive Mixed Agrifood Systems
BHR	Bahrain	Modern Agrifood Systems
BGD	Bangladesh	Capital-Intensive Mixed Agrifood Systems
BLR	Belarus	Land-Intensive Mixed Agrifood Systems
BEL	Belgium	Modern Agrifood Systems
BEN	Benin	Traditional Agrifood Systems
BOL	Bolivia (Plurinational State of)	Land-Intensive Mixed Agrifood Systems
BIH	Bosnia and Herzegovina	Land-Intensive Mixed Agrifood Systems
BWA	Botswana	Traditional Agrifood Systems
BRA	Brazil	Land-Intensive Mixed Agrifood Systems
BGR	Bulgaria	Land-Intensive Mixed Agrifood Systems
BFA	Burkina Faso	Traditional Agrifood Systems
BDI	Burundi	Traditional Agrifood Systems
KHM	Cambodia	Capital-Intensive Mixed Agrifood Systems
CMR	Cameroon	Traditional Agrifood Systems
CAN	Canada	Modern Agrifood Systems
CAF	Central African Republic	Traditional Agrifood Systems
TCD	Chad	Traditional Agrifood Systems
CHL	Chile	Land-Intensive Mixed Agrifood Systems
CHN	China	Capital-Intensive Mixed Agrifood Systems
HKG	China, Hong Kong SAR	Modern Agrifood Systems
COL	Colombia	Land-Intensive Mixed Agrifood Systems
COM	Comoros (the)	Capital-Intensive Mixed Agrifood Systems
COG	Congo (the)	Traditional Agrifood Systems
CRI	Costa Rica	Capital-Intensive Mixed Agrifood Systems
CIV	Côte d'Ivoire	Land-Intensive Mixed Agrifood Systems
HRV	Croatia	Modern Agrifood Systems
CUB	Cuba	Land-Intensive Mixed Agrifood Systems
CYP	Cyprus	Modern Agrifood Systems
CZE	Czechia	Modern Agrifood Systems
PRK	Democratic People's Republic of Korea (the)	Traditional Agrifood Systems

TABLE A1 (cont.) List of countries by agrifood system group

Country ISO3 code	Country name	Agrifood system group
COD	Democratic Republic of the Congo (the)	Traditional Agrifood Systems
DNK	Denmark	Modern Agrifood Systems
DJI	Djibouti	Traditional Agrifood Systems
DOM	Dominican Republic (the)	Capital-Intensive Mixed Agrifood Systems
ECU	Ecuador	Capital-Intensive Mixed Agrifood Systems
EGY	Egypt	Capital-Intensive Mixed Agrifood Systems
SLV	El Salvador	Capital-Intensive Mixed Agrifood Systems
GNQ	Equatorial Guinea	Capital-Intensive Mixed Agrifood Systems
ERI	Eritrea	Traditional Agrifood Systems
EST	Estonia	Modern Agrifood Systems
SWZ	Eswatini	Land-Intensive Mixed Agrifood Systems
ETH	Ethiopia	Traditional Agrifood Systems
FIN	Finland	Modern Agrifood Systems
FRA	France	Modern Agrifood Systems
GAB	Gabon	Land-Intensive Mixed Agrifood Systems
GMB	Gambia (the)	Traditional Agrifood Systems
GEO	Georgia	Capital-Intensive Mixed Agrifood Systems
DEU	Germany	Modern Agrifood Systems
GHA	Ghana	Capital-Intensive Mixed Agrifood Systems
GRC	Greece	Modern Agrifood Systems
GTM	Guatemala	Capital-Intensive Mixed Agrifood Systems
GIN	Guinea	Traditional Agrifood Systems
GNB	Guinea-Bissau	Traditional Agrifood Systems
GUY	Guyana	Land-Intensive Mixed Agrifood Systems
HTI	Haiti	Traditional Agrifood Systems
HND	Honduras	Capital-Intensive Mixed Agrifood Systems
HUN	Hungary	Modern Agrifood Systems
IND	India	Capital-Intensive Mixed Agrifood Systems
IDN	Indonesia	Capital-Intensive Mixed Agrifood Systems
IRN	Iran (Islamic Republic of)	Land-Intensive Mixed Agrifood Systems
IRQ	Iraq	Land-Intensive Mixed Agrifood Systems
IRL	Ireland	Modern Agrifood Systems
ISR	Israel	Modern Agrifood Systems
ITA	Italy	Modern Agrifood Systems
JAM	Jamaica	Capital-Intensive Mixed Agrifood Systems
JPN	Japan	Modern Agrifood Systems
JOR	Jordan	Land-Intensive Mixed Agrifood Systems
KAZ	Kazakhstan	Land-Intensive Mixed Agrifood Systems
KEN	Kenya	Traditional Agrifood Systems
KWT	Kuwait	Capital-Intensive Mixed Agrifood Systems
KGZ	Kyrgyzstan	Traditional Agrifood Systems
LAO	Lao People's Democratic Republic (the)	Capital-Intensive Mixed Agrifood Systems
LVA	Latvia	Modern Agrifood Systems
LBN	Lebanon	Capital-Intensive Mixed Agrifood Systems
LSO	Lesotho	Traditional Agrifood Systems
LBR	Liberia	Traditional Agrifood Systems
LBY	Libya	Land-Intensive Mixed Agrifood Systems

TABLE A1 (cont.) List of countries by agrifood system group

Country ISO3 code	Country name	Agrifood system group
LTU	Lithuania	Land-Intensive Mixed Agrifood Systems
MDG	Madagascar	Traditional Agrifood Systems
MWI	Malawi	Traditional Agrifood Systems
MYS	Malaysia	Modern Agrifood Systems
MLI	Mali	Traditional Agrifood Systems
MRT	Mauritania	Traditional Agrifood Systems
MUS	Mauritius	Modern Agrifood Systems
MEX	Mexico	Land-Intensive Mixed Agrifood Systems
MNG	Mongolia	Land-Intensive Mixed Agrifood Systems
MAR	Morocco	Land-Intensive Mixed Agrifood Systems
MOZ	Mozambique	Traditional Agrifood Systems
MMR	Myanmar	Capital-Intensive Mixed Agrifood Systems
NAM	Namibia	Land-Intensive Mixed Agrifood Systems
NPL	Nepal	Traditional Agrifood Systems
NLD	Netherlands (the)	Modern Agrifood Systems
NZL	New Zealand	Modern Agrifood Systems
NIC	Nicaragua	Traditional Agrifood Systems
NER	Niger (the)	Traditional Agrifood Systems
NGA	Nigeria	Capital-Intensive Mixed Agrifood Systems
MKD	North Macedonia	Land-Intensive Mixed Agrifood Systems
NOR	Norway	Modern Agrifood Systems
OMN	Oman	Land-Intensive Mixed Agrifood Systems
PAK	Pakistan	Capital-Intensive Mixed Agrifood Systems
PSE	Palestine	Capital-Intensive Mixed Agrifood Systems
PAN	Panama	Land-Intensive Mixed Agrifood Systems
PNG	Papua New Guinea	Capital-Intensive Mixed Agrifood Systems
PRY	Paraguay	Land-Intensive Mixed Agrifood Systems
PER	Peru	Land-Intensive Mixed Agrifood Systems
PHL	Philippines (the)	Capital-Intensive Mixed Agrifood Systems
POL	Poland	Capital-Intensive Mixed Agrifood Systems
PRT	Portugal	Modern Agrifood Systems
PRI	Puerto Rico	Modern Agrifood Systems
QAT	Qatar	Modern Agrifood Systems
KOR	Republic of Korea (the)	Modern Agrifood Systems
MDA	Republic of Moldova (the)	Land-Intensive Mixed Agrifood Systems
ROU	Romania	Capital-Intensive Mixed Agrifood Systems
RUS	Russian Federation (the)	Land-Intensive Mixed Agrifood Systems
RWA	Rwanda	Traditional Agrifood Systems
SAU	Saudi Arabia	Land-Intensive Mixed Agrifood Systems
SEN	Senegal	Traditional Agrifood Systems
SRB	Serbia	Capital-Intensive Mixed Agrifood Systems
SLE	Sierra Leone	Traditional Agrifood Systems
SGP	Singapore	Modern Agrifood Systems
SVK	Slovakia	Modern Agrifood Systems
SVN	Slovenia	Modern Agrifood Systems
SLB	Solomon Islands	Capital-Intensive Mixed Agrifood Systems
SOM	Somalia	Traditional Agrifood Systems

TABLE A1 (cont.) List of countries by agrifood system group

Country ISO3 code	Country name	Agrifood system group
ZAF	South Africa	Land-Intensive Mixed Agrifood Systems
SSD	South Sudan	Traditional Agrifood Systems
ESP	Spain	Modern Agrifood Systems
LKA	Sri Lanka	Capital-Intensive Mixed Agrifood Systems
SDN	Sudan (the)	Land-Intensive Mixed Agrifood Systems
SUR	Suriname	Land-Intensive Mixed Agrifood Systems
SWE	Sweden	Modern Agrifood Systems
CHE	Switzerland	Modern Agrifood Systems
SYR	Syrian Arab Republic (the)	Land-Intensive Mixed Agrifood Systems
TWN	Taiwan Province of China	Modern Agrifood Systems
TJK	Tajikistan	Traditional Agrifood Systems
THA	Thailand	Capital-Intensive Mixed Agrifood Systems
TLS	Timor-Leste	Capital-Intensive Mixed Agrifood Systems
TGO	Togo	Traditional Agrifood Systems
TTO	Trinidad and Tobago	Land-Intensive Mixed Agrifood Systems
TUN	Tunisia	Land-Intensive Mixed Agrifood Systems
TUR	Turkey	Capital-Intensive Mixed Agrifood Systems
TKM	Turkmenistan	Land-Intensive Mixed Agrifood Systems
UGA	Uganda	Traditional Agrifood Systems
UKR	Ukraine	Land-Intensive Mixed Agrifood Systems
ARE	United Arab Emirates (the)	Modern Agrifood Systems
GBR	United Kingdom of Great Britain and Northern Ireland (the)	Modern Agrifood Systems
TZA	United Republic of Tanzania (the)	Traditional Agrifood Systems
USA	United States of America (the)	Modern Agrifood Systems
URY	Uruguay	Land-Intensive Mixed Agrifood Systems
UZB	Uzbekistan	Land-Intensive Mixed Agrifood Systems
VEN	Venezuela (Bolivarian Republic of)	Land-Intensive Mixed Agrifood Systems
VNM	Viet Nam	Capital-Intensive Mixed Agrifood Systems
YEM	Yemen	Land-Intensive Mixed Agrifood Systems
ZMB	Zambia	Traditional Agrifood Systems
ZWE	Zimbabwe	Capital-Intensive Mixed Agrifood Systems

Source: Authors' own elaboration.

Annex 2. The PROSA Global Analysis – methodological note

The PROSA Global Analysis adopts a multistage mixed method framework to identify key drivers, and specific relationships with the sustainable agriculture indicators that are empirically robust, conceptually valid, and relevant to policy interventions. The PROSA Global Analysis approach entails the following five steps.

Step 1. Review literature to identify drivers of sustainable agriculture and their impact on sustainable agriculture sub-indicators

The PROSA Global Analysis began by compiling a broad list of drivers that were likely to influence changes in SDG indicator 2.4.1's sub-indicators of sustainable agriculture, and their relationships with those sub-indicators. The report restricted its focus to drivers that can be influenced directly by policies and can be quantified and aggregated to the national level. As a result, critical biophysical drivers of agricultural change, such as rainfall, temperature, and soil nutrient content, were not considered. This initial list of drivers was developed through a combination of extensive reviews of empirical and theoretical studies, combined with consultations with thematic experts within FAO. A total of 13 driver groups and 30 drivers of agricultural change and sustainability were identified in both peer-reviewed and grey literature. The relationships between these drivers and the sub-indicators were then categorized based on the direction of the relationships found in literature. The inventory of reviewed literature and the full display of driver/sub-indicator relationships is available upon request.

Step 2. Identify quantitative proxies for the drivers

The next step was to screen publicly available global data, to identify quantitative variables to proxy for the respective drivers for which data are widely available temporally and geographically, and that lend themselves to conceptually clear interpretations. Sixty-eight quantitative proxies for the 32 drivers were identified and for which data was collected. In most cases, several measurements are possible. Where multiple potential proxies of drivers of agricultural change exist, they are often highly correlated, creating analytical challenges for assessing independent relationships between drivers and sub-indicators of sustainable agriculture. To reduce the intercorrelations to the extent possible, a preselection of driver indicators was made to include the most valid and reliable proxies, with the widest country coverage.

Step 3. Select drivers to analyse

The selection of key drivers of change in sustainable agriculture and their quantitative indicators included in this report was done through an iterative process, based on: (1) relevance in literature; (2) reliability and country coverage of the driver proxy; and (3) clear visual relationships with the sub-indicator proxies. Additionally, drivers that were specific to sustainable agriculture and had narrower measurements for more focused policy analysis were prioritized.

Government support to agriculture, for instance, can be measured in terms of nominal rates of assistance to agricultural outputs and inputs, total government spending outlays to agriculture per capita, or the ratio between the share of government expenditure to agriculture and the agriculture share of GDP. Nominal rates of government assistance were selected due to wider country coverage, and better ability to distinguish the type of government support for a more focused analysis.

According to these specifications, five key driver groups emerged:

1. **demographic factors** including population dynamics and rural-urban changes, measured as the ratio of youth and rural population growth to total population growth;

2. **inequalities** in the distribution of income and access to resources, and gender-related inequalities, measured as the Gini index and the GII;
3. **structure of the farming sector**, measured as the average farm size and degree of mechanization;
4. **integration of the agricultural sector into the global economy**, measured as foreign direct investment inflows into agriculture and the share of exports in agricultural production;
5. **governmental support to the agricultural sector** measured as nominal rates of government assistance to agricultural inputs and outputs.

In addition, a group of general country characteristics are included in the subsequent empirical analysis, to control for the general state of the economy in order to better isolate the incremental effect of the key drivers of sustainable agriculture independent of the economic conditions of the country. The country characteristics include proxies for education levels, nationwide infrastructure, institutional structures to support sustainable agriculture, GDP per capita, and labour force composition.

Step 4. Empirical analysis using computational selection procedure

To quantitatively identify the most powerful interactions between drivers and sub-indicators of sustainable agriculture, an empirical approach known as the Least Absolute Shrinkage and Selection Operator (LASSO) approach is used. The LASSO approach allows for the selection of drivers that exhibit quantitatively strong relationships with the sub-indicators of sustainable agriculture (see Box 8 for details on the LASSO approach).

In particular, the LASSO approach addresses many of the empirical challenges of an assessment of these relationship at a national scale. A fundamental challenge of the empirical identification of driver/sub-indicator relationships is that, in principle, each of the potential drivers identified can influence each sub-indicator. This causes difficulties for standard econometric approaches, including multi-collinearity between drivers, the possibility of reverse causality and hence identification problems, and overspecification due to the inclusion of a large number of independent variables (drivers) with a limited number or sparse observations for some countries or drivers. The LASSO approach is designed to address these challenges by excluding drivers from specific sub-indicator interactions when country-level data coverage and observation numbers are limited.[1]

BOX 8 Implementation of the LASSO approach

The LASSO procedure (Tibshirani, 1996) is based on the minimization of squared residuals. However, it also minimizes the absolute value of all estimation coefficients, such that some independent variables can be excluded from the estimation:

$$\min_{\boldsymbol{\beta},\boldsymbol{\gamma},\alpha} J = \boldsymbol{\varepsilon}^{\mathbf{T}}\boldsymbol{\varepsilon} + \alpha\boldsymbol{\iota}^{\mathbf{T}}\left|\boldsymbol{\beta}\right| + \alpha\boldsymbol{\iota}^{\mathbf{T}}\left|\boldsymbol{\gamma}\right|$$

BOX 8 (cont.) **Implementation of the LASSO approach**

This objective function is minimized by choosing the optimal values for the coefficients **β** for the driver proxies and coefficients **γ** for a set of country characteristics. The weighting factor **α** can take values between 0 and large positive numbers, and reflects the impact of the penalty term on the overall model. The residuals are defined as the difference between sustainability indicator **S** and the combined effects of drivers **D** and characteristics **C**:

$$\varepsilon^i = S^i - D\beta^i - C\gamma^i$$

where:

S = indicators for sustainable agriculture

D = drivers

C = country-specific characteristics

β = estimation coefficients

ε = residual

γ = weighting factor for penalty term on absolute coefficients values

Source: Tibshirani, 1996.

Step 5. Final selection of driver and indicator relationships

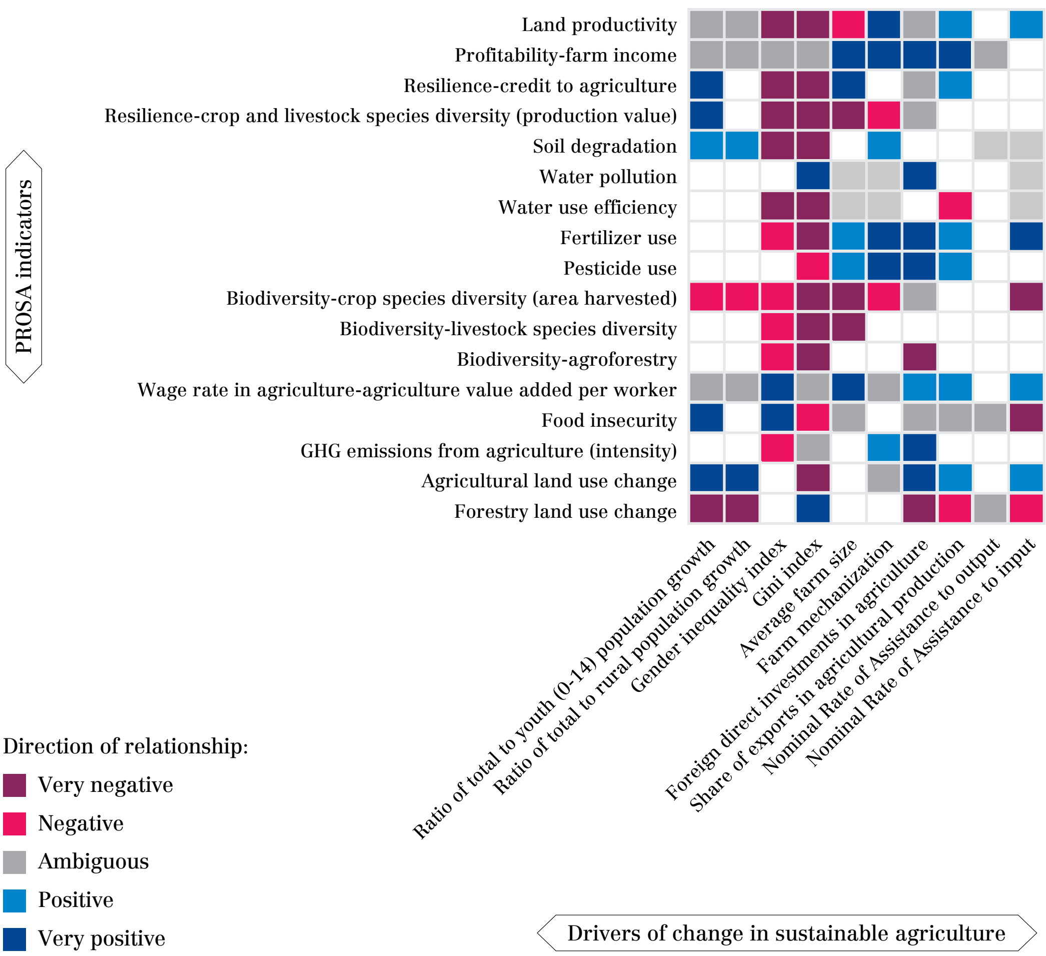
In the final step, results from the literature and the LASSO on the relationships between the five key driver groups and each sub-indicator of sustainable agriculture are summarized and compared according to the general magnitude and direction of the relationships.

To account for heterogeneity in the literature, a ranking scale is developed. In cases where the general tendency in the literature is in a particular direction, but alternative evidence is found, the result is labelled as either positive or negative. By contrast, if the results are more consistently in one direction, or are evenly split, the result is summarized as very positive/negative, or ambiguous, respectively. Figure A1 summarizes the literature-based ranking exercise of drivers for the subset of drivers considered in the analysis.

Figure A2 summarizes the findings from the LASSO procedures described above. The final selection of the relationships between the drivers of agricultural change and the sub-indicators of sustainable agriculture included in this report was made by layering the empirical results of the LASSO analysis over the analysis of the literature (see Figure A3), based on the following two criteria. First, a strong relationship was identified in the LASSO analysis, suggesting an empirical association between the driver and the sub-indicator of sustainable agriculture. Second, the direction of this empirical relationship (that is, positive or negative) is supported by existing literature, and thus has a conceptual justification under certain conditions. For these reasons, several sub-indicator proxies are dropped from the analysis, including fertilizer use, GHG emissions and land use change.

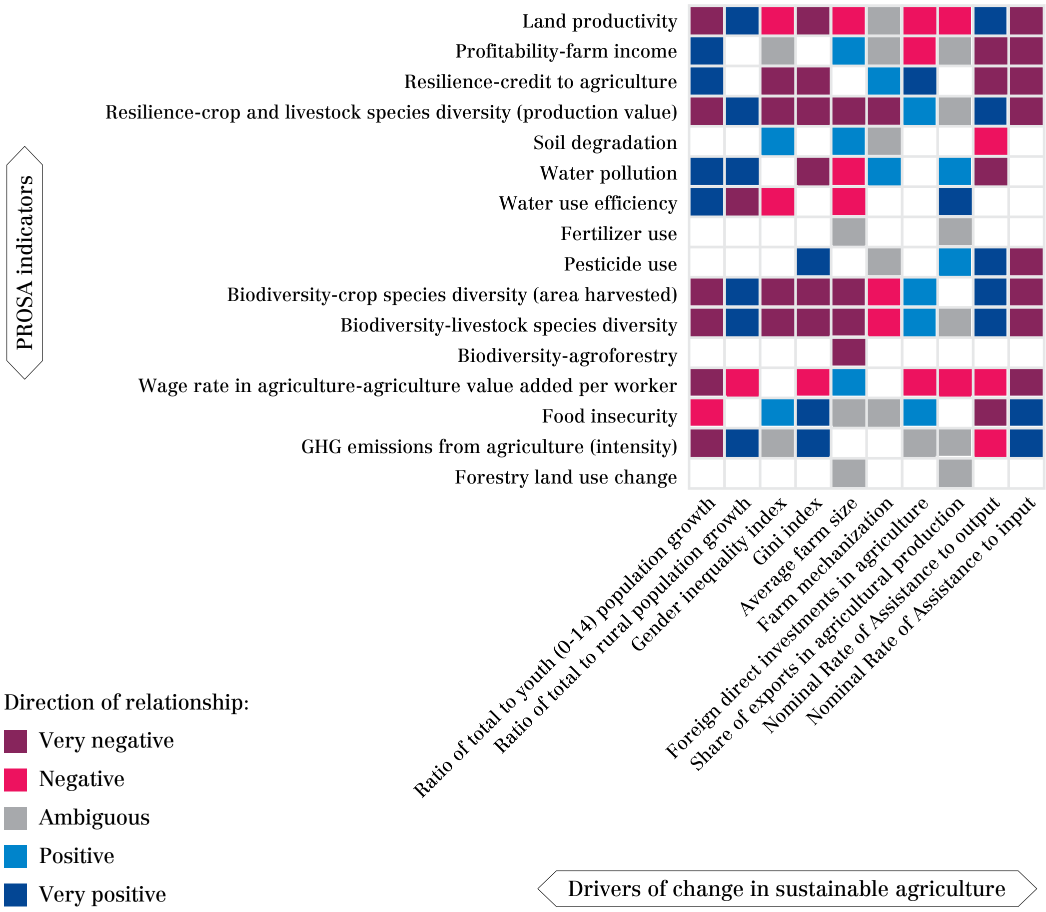
Through the multiple steps of the PROSA Global Approach, the 68 potential drivers of agricultural change are reduced to five key driver groups. These drivers are empirically and conceptually associated with the proxy sub-indicators of SDG indicator 2.4.1, through 29 relationships analysed in detail in the study.

FIGURE A1 Selected driver/sub-indicator relations from literature review



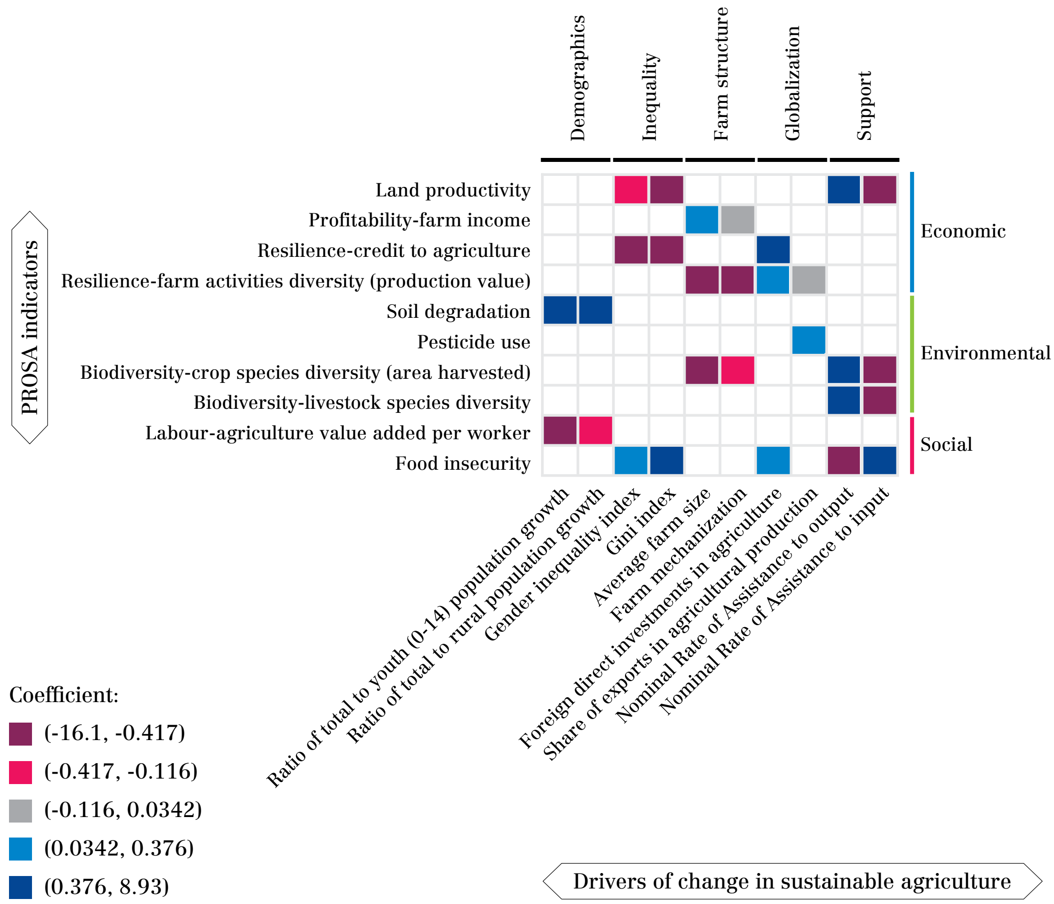
Source: Authors' own elaboration.

FIGURE A2 Selected driver/sub-indicator relations from LASSO results (2007–2016 average)



Source: Authors' own elaboration.

FIGURE A3 Final selection of relationships between drivers and sustainable agriculture sub-indicators, based on literature review and machine learning – LASSO analysis



Source: Authors' own elaboration.

The Progress towards Sustainable Agriculture initiative (PROSA) is a framework that seeks to complement ongoing efforts on the Sustainable Development Goals (SDGs), and particularly indicator 2.4.1, to support country-level assessments using data already available at the national level. Making agriculture more sustainable – productive, environmentally friendly, resilient and profitable is fundamental, as agriculture remains the main source of livelihood for the majority of the world's poor and hungry. The pathway towards sustainable agriculture must ensure increasing output, but also make more efficient use of increasingly scarce global resources, be resilient to and help mitigate climate change, and improve human well-being.

This technical study examines the key factors driving changes in trends in the indicators of sustainable agriculture and provides decision-makers with insights into viable options for achieving this goal. The study identifies five key groups of drivers that most influence these indicators globally. The ways in which each driver affects the multiple dimensions of sustainability highlights the interconnections, synergies and trade-offs that must be managed in different global contexts to achieve agricultural sustainability. The analysis can help decision-makers operating in different country contexts to identify practical solutions to ensure that their interventions contribute positively to a more sustainable agriculture.

The FAO Agricultural Development Economics Technical Study series collects technical papers addressing policy-oriented assessments of economic and social aspects of food security and nutrition, sustainable agriculture and rural development.

The series is available at www.fao.org/economic/esa/technical-studies

FOR FURTHER INFORMATION

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