Chapter 3

Monitoring the environmental efficiency and natural resource productivity of agriculture

Tracking trends in decoupling inputs to production from economic growth is an important issue for monitoring progress towards green growth. Indicators included in this chapter attempt to capture the extent to which economic growth is becoming greener, that is, low-carbon and resource-efficient. The indicators presented pertain to: i) carbon and energy productivity, which characterises, among other things, interactions with the climate system and the global carbon cycle as well as the environmental and economic efficiency with which energy resources are used in agricultural production; ii) resource productivity, which characterises the environmental and economic efficiency with which natural resources such as water and nutrients are used in production; and iii) environmentally adjusted total factor productivity in order to give a more complete picture of the productivity of an economy by accounting for inputs from natural resources and for the generation of pollution.

The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

Indicators that monitor the environmental efficiency and natural resource productivity of agriculture attempt to track the extent to which economic growth is becoming greener (low-carbon and resource-efficient). Tracking trends in the decoupling of inputs to production from economic growth is thus an important focus for monitoring. To achieve this, indicators that focus on environment-related "productivity," or its inverse, "intensity," should be used. Such indicators include those that monitor the productivity of natural resources and materials used in agricultural production (**Box 3.1**).

Improvements in resource productivity (i.e. reducing the amount of resources used per unit of economic output) imply that less resources per unit of economic activity (e.g. agricultural GDP) will be required in the future. Monitoring natural resource and environmental productivity for agriculture is important because of the sector's significant role in using natural resources, making the productivity of soil and water resources of utmost importance.

Box 3.1. The resource productivity concept

Resource productivity refers to the effectiveness with which an economy or a production process is using natural resources. It should ideally encompass all natural resources and ecosystem inputs that are used as factors of production in the economy. This term, however, is often used as a synonym for material productivity. Productivity measurement and analysis of natural resource and material flows complement the traditional indicators of capital, land and labour productivity. Used in parallel, these three types of productivity indicators afford a much deeper understanding of total factor productivity. While there is no disagreement on this general notion, a look at the productivity literature and its various applications reveals there is no single purpose or indicator to measure productivity. Productivity can be defined with respect to:

- The economic-physical efficiency (i.e. the value of output or value added generated per unit of resource inputs used).
- The physical or technical efficiency (i.e. the amount of resources input required to produce a unit of output, both expressed in physical terms, such as land for the production of cereals). The focus is on maximising the output with a given set of inputs and a given technology or on minimising the inputs for a given output.
- The economic efficiency (i.e. the money value of outputs relative to the money value of inputs). The focus is on minimising resource input costs.

The OECD places "resource productivity" within a welfare perspective. It is understood to contain both a quantitative dimension (e.g. the quantity of output produced with a given input of natural resources) and a qualitative dimension (e.g. the environmental impacts per unit of output produced with a given natural resource input).

Improving resource productivity is often assumed to lead to a parallel reduction in environmental impact to help avert the possibility of resource scarcity and environmental degradation. However, unless such improvements outweigh economic growth, there is a risk that the associated negative environmental impacts might increase. Protecting and managing the natural resource base cannot, therefore, rely on improvements in resource productivity alone; it will also be necessary to de-link economic growth from environmental pressures (**Box 3.2**). While productivity indicators and their inverse − decoupling trends − show whether production has become *greener* in *relative* terms, they do not show whether environmental pressure has also diminished in *absolute* terms. From an environmental perspective it is useful to also monitor the presence of absolute decoupling.

Box 3.2. Decoupling concepts

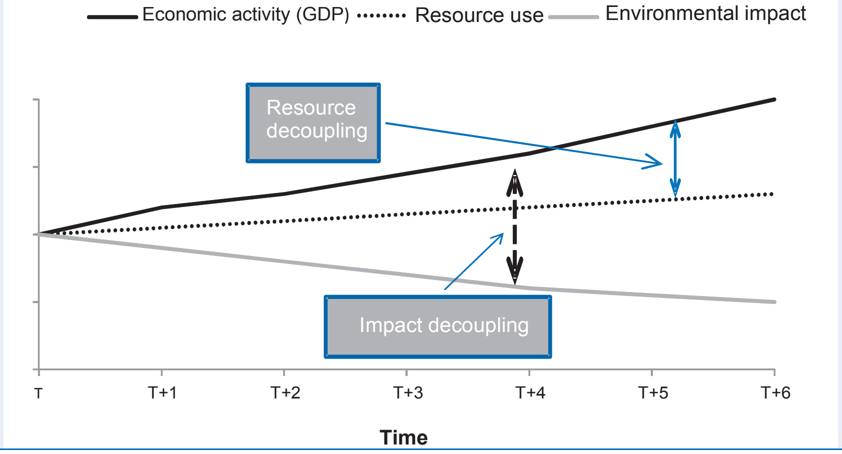
De-linking − commonly called decoupling − environmental impacts from economic growth is a core goal of the OECD Green Growth Strategy. The concept of resource decoupling was officially endorsed by OECD Environment Ministers in 2001 and is considered a main objective in the Environmental Strategy for the First Decade of the 21st Century (www.oecd.org/dataoecd/33/40/1863539.pdf). The OECD was mandated to undertake the task of developing a set of indicators to measure progress across the three dimensions of sustainable development. They include indicators to measure the decoupling of economic growth from environmental degradation that might also be used in conjunction with other indicators in the OECD's economic, social, and environmental peer review processes (OECD, 2002).

There are two types of decoupling, commonly referred to as *absolute* and *relative* decoupling. Decoupling is said to be relative when the relevant environmental parameter (e.g. resources used, or a measure of environmental impact) is increasing at a slower rate than the relevant economic variable (e.g. GDP); that is, the economy is growing faster than resource use, while the absolute quantity of the resource input is still increasing (i.e. the elasticity is positive, but less than unity). Such relative decoupling appears to be fairly common. Decoupling is said to be absolute when the economic variable is growing, while the environmental variable is stable or decreasing.

The decoupling concept, however, does not automatically capture the environmental impacts associated with economic growth. The relationship between resource use, environmental pressures and environmental impacts is complex. Taking resource-use as a proxy for environmental impacts can be misleading: first, the entire life-cycle of resources, from their extraction, through their use in the production of goods and services and subsequent use phase, to the waste phase, gives rise to environmental impacts; second, any given natural resource material can take numerous different pathways through the economy, which can change with time (as a result of technical or social developments, for example); third, differences in regional conditions and use patterns also need to be considered. Furthermore, the extent of the environmental impact varies according to the resources used.

For these reasons, two dimensions of decoupling as applied to green growth are distinguished in the literature: *resource* decoupling and *impact* decoupling (**Figure 3.1)**. The former addresses the link between economic growth versus resource use, while the latter refers to the link between economic growth versus environmental impact (i.e. increasing economic output while reducing negative environmental impacts) (UNEP, 2011). In terms of methodology and data collection, impact decoupling is usually very demanding at the aggregate level (national or sectoral) as many environmental impacts, which may have quite different trends, need to be considered, and the weighting procedures necessary for aggregating the impacts might be seen as subjective. Moreover, a negative relation between these two concepts of decoupling might occur, as reducing environmental impact does not necessarily have a mitigating impact on resource scarcity or production costs, and may even increase them. There is a significant volume of theoretical and empirical studies which examines whether or not increased efficiency leads to environmental improvements; the so-called "rebound effect" or Jevons' paradox. In general, the magnitude of the rebound effect is driven by the degree of substitution between factors of production (e.g. energy, capital) (Sorrell, 2009; Sorrell, Dimitropoulos and Sommerville, 2009).

Figure 3.1. Stylised representation of resource and impact decoupling



Moreover, productivity or intensity indicators need to be gauged in the specific (country) context regarding the country's level of development or endowment of natural assets. Specific indicators selected for this group should track the productivity of those natural resources that are most important to domestic agricultural production. Thus, specific indicators selected in this group will vary across countries. For example, indicators related to the intensity of water use in agriculture may be considered irrelevant by those countries possessing abundant water resources.

Other indicators, however, will be common across countries, in particular those that are global in nature, such as climate change. The atmosphere's capacity to absorb Green House Gases (GHGs) is a global asset and the environmental efficiency of GHG emissions is relevant independent of the country or region in question. Similarly, energy is a critical input into agricultural production and energy productivity is important around the world.

Another limitation of partial indicators is that rising productivity may also be the result of the substitution of natural assets for other inputs (labour, capital, energy) or an overall rise in the efficiency of the production process from improved technology or organisation (i.e. a multi-factor productivity increase). Care must be taken when interpreting partial productivity measures, although the caveats relating to environmental productivity do not differ from those relating, for instance, to traditional partial productivity indicators (e.g. labour productivity). Overall, changes in the natural resource and environmental productivity indicators need to be carefully interpreted. **Table 3.1** presents the proposed indicators in this area.

Table 3.1. Environmental efficiency and natural resource productivity/intensity indicators

Theme	Indicators	Criteria			
		Capturing the nexus between the environment and the economy	Ease of communication for different users and audiences	Reflecting key global environmental issues	Measurability and comparability across countries
Carbon productivity	Agricultural GDP per unit of agricultural GHG emissions	***	***	***	***
	Supplementary indicators				
	Share of agriculture in total GHG emissions	***	***	***	***
	Productivity of GHG emission from agriculture by source (soil, ruminants, manure management)	***	***	***	***
Energy productivity	Agricultural GDP per unit of energy use	***	***	***	***
	Renewable energy produced by agriculture	***	***	***	*
Water use intensity	Irrigation water per irrigated area	***	***	***	*
Nutrient flows and balances	Nutrient (N and P) intensities per area of agricultural land	***	***	***	***
	Nutrient balances in agriculture (N and P) per agricultural output and area	***	***	***	**
	Intensity of commercial fertilisers	***	***	**	***
Material (biomass) productivity		Indicators to be developed			
Multifactor productivity	Environmentally adjusted total factor productivity	***	**	*	*

Carbon productivity

Policy context

Agricultural production not only uses environmental resources as inputs, it also places pressure on the environment by emitting pollutants such as GHGs, therefore contributing to climate change. Agriculture is highly exposed to climate change, which may have an impact on yields, location of production and costs of production and thus with potential risks for food supply, food prices and farm incomes.

The relationship between agriculture and climate change is complex. Agriculture not only contributes to GHGs, but it also provides a carbon sink function under certain management practices. Moreover, agriculture is subject to the impact of climate change. While farming is a source of GHGs, principally methane (CH_4) and nitrous oxide (N_2O), which are part of the primary driving force behind climate change, climate change may also impact on farm production.

Although there are no specific agricultural commitments under the United Nations Framework Convention on Climate Change (UNFCCC) to reduce GHG emissions, many OECD countries are developing agricultural climate change programmes aimed at reducing GHGs, promoting carbon sinks, and making agriculture more resilient to the impact of climate change. A key challenge in relation to agriculture and agricultural GHG emissions is to reduce the overall level and rate of emission release per unit volume of agricultural production.

Monitoring progress

The progress of green growth in agriculture can be assessed against trends in agricultural GHG emissions and the level of decoupling achieved between GHGs and economic growth in agriculture. The proposed indicator relates to the carbon productivity of agriculture defined as the amount of agricultural GDP per unit of carbon equivalents emitted by agriculture.[1] Increasing carbon productivity is key to addressing the twin challenge of mitigating climate change and managing economic growth.

Supplementary indicators might include: i) share of agriculture in total GHG emissions; ii) productivity of agriculture GHG emissions by source: soil denitrification, fermentation of ruminants, manure decomposition and rice cultivation.

GHG productivity is already used as an indicator in OECD and other international organisations that work on green growth. It is widely accepted and easy to interpret.

Measurability

UNFCCC inventories are the main data source. Measurability of indicators is good, as data on GHG emissions are reported annually by Annex I countries to the UNFCCC. The data cover all OECD countries, except Chile, Israel, Korea and Mexico. Emissions are expressed in CO_2-equivalents, as different GHGs have a different global warning potential. The main sources of agricultural GHG emissions are:

- Methane (CH_4) emissions, through enteric fermentation in ruminant animals (cattle, sheep and goats).
- Nitrous oxide (N2O) emissions, produced by soil denitrification.
- CH4 and N2O emissions, from manure decomposition.

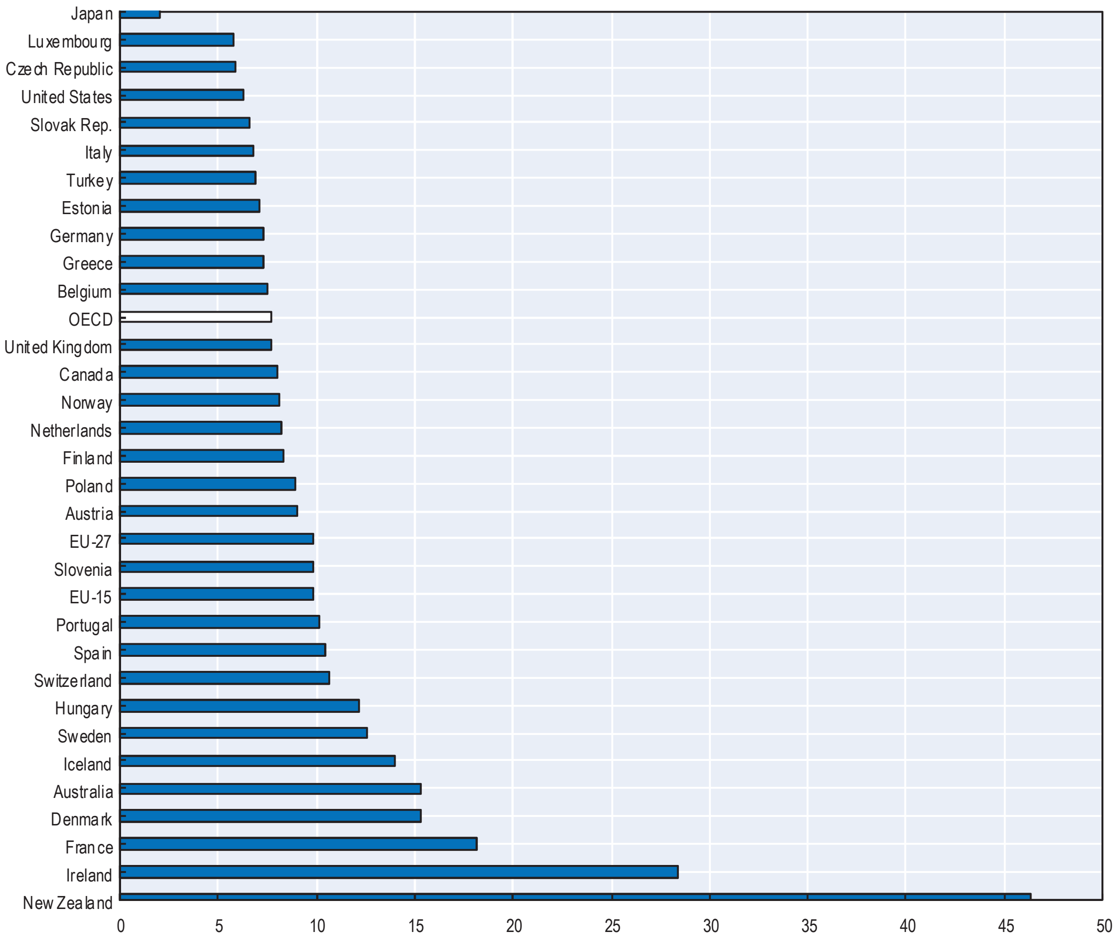
These biochemical processes generally depend on climate, agronomic and technological conditions which can affect agricultural soils and manure storage facilities. Methane and nitrous oxide emissions are closely related to livestock production. Since these different

GHG, have different global warming potential, the data are expressed in terms of emissions of CO2-equivalent in order to make them comparable.

Main trends

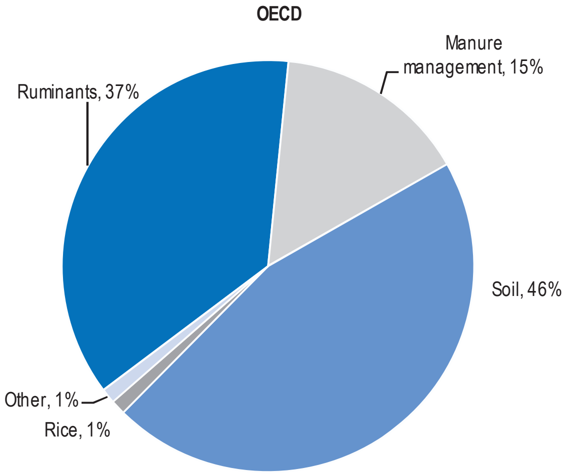
Primary agriculture in the OECD area accounts, on average, for 8% of total GHGs in the OECD area (**Figure 3.2**). Soil de-nitrification is the main source of GHGs from agriculture (46%), followed by fermentation of ruminants (37%) and manure management (15%) (**Figure 3.3)** Over the period 1990-2010, total OECD agricultural GHG emissions decreased slightly (**Figure 3.4)**. Over the same period, agricultural production steadily increased, suggesting that for the OECD area as a whole there has been an improvement in the environmental efficiency of agricultural GHG emissions (**Figure 3.5**). In several cases, absolute decoupling of GHG emissions from agricultural production is observed (**Figure 3.6)**. Differences between OECD countries in GHG productivity remain high (**Figure 3.7)**. Productivity of GHGs produced by soil de-nitrification, fermentation of ruminants and manure decomposition increased steadily over the 1990-2010 period; productivity of GHGs produced by rice cultivation, on the other hand, exhibited somewhat more variable trends (**Figure 3.8**).

Figure 3.2. Share of agriculture in total GHG emissions, 2008-10 (%)



Note: Excluding LULUCF (land use, land use-change and forestry).
Source: UNFCCC *Greenhouse Gas Inventory Data*, http://unfccc.int/ghg_data/items/3800.php.
StatLink http://dx.doi.org/10.1787/888933144569

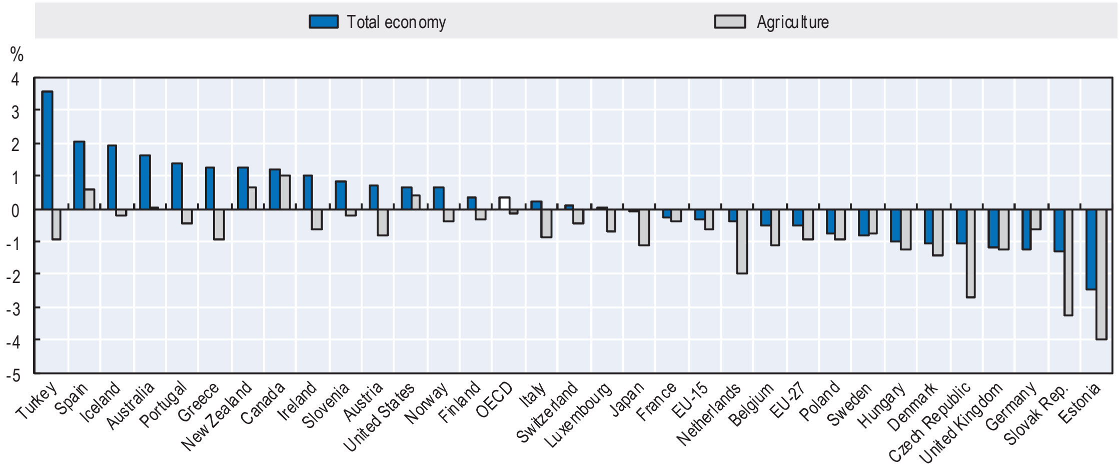
Figure 3.3. GHG emissions from agriculture in the OECD area, by source, 2008-10 (%)



Note: Excluding LULUCF (land use, land use-change and forestry).
Source: UNFCCC *Greenhouse Gas Inventory Data*, http://unfccc.int/ghg_data/items/3800.php.

StatLink http://dx.doi.org/10.1787/888933144573

Figure 3.4. Growth rate of total economy and agricultural net GHG emissions

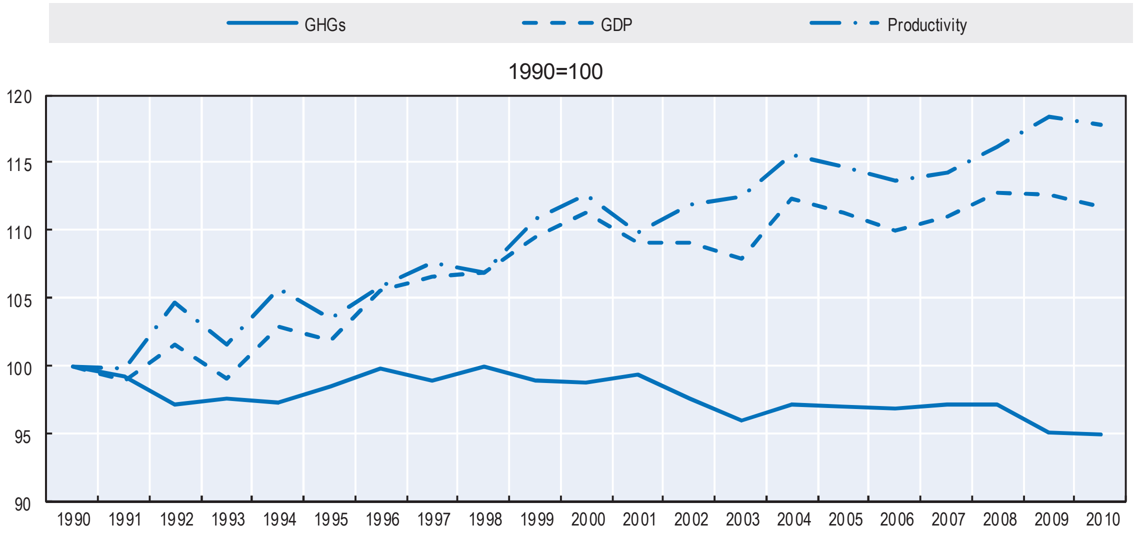


Note: Excluding LULUCF (land use, land use-change and forestry).

Source: UNFCCC *Greenhouse Gas Inventory Data*, http://unfccc.int/ghg_data/items/3800.php.

StatLink http://dx.doi.org/10.1787/888933144584

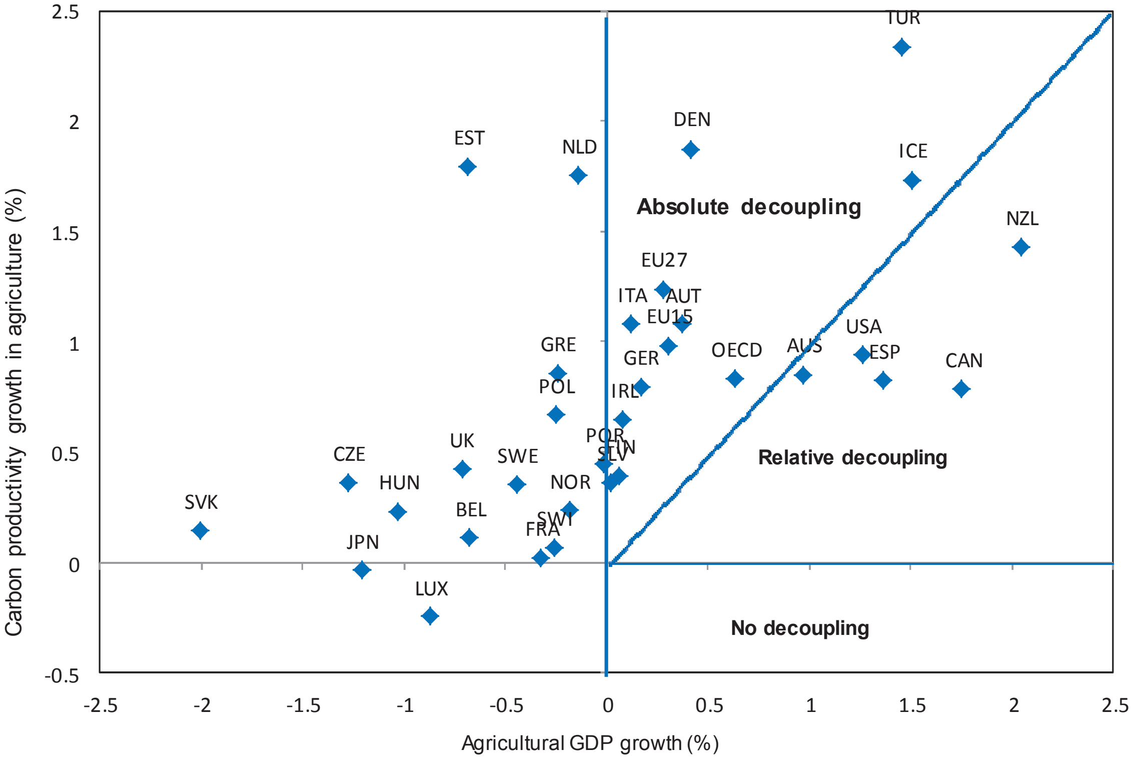
Figure 3.5. GHG emissions, GDP and productivity for agriculture in the OECD area



Note: Excluding LULUCF (land use, land use-change and forestry).
Source: UNFCCC *Greenhouse Gas Inventory Data*, http://unfccc.int/ghg_data/items/3800.php; FAO, *FAOSTAT* (database), http://faostat.fao.org/.

StatLink http://dx.doi.org/10.1787/888933144592

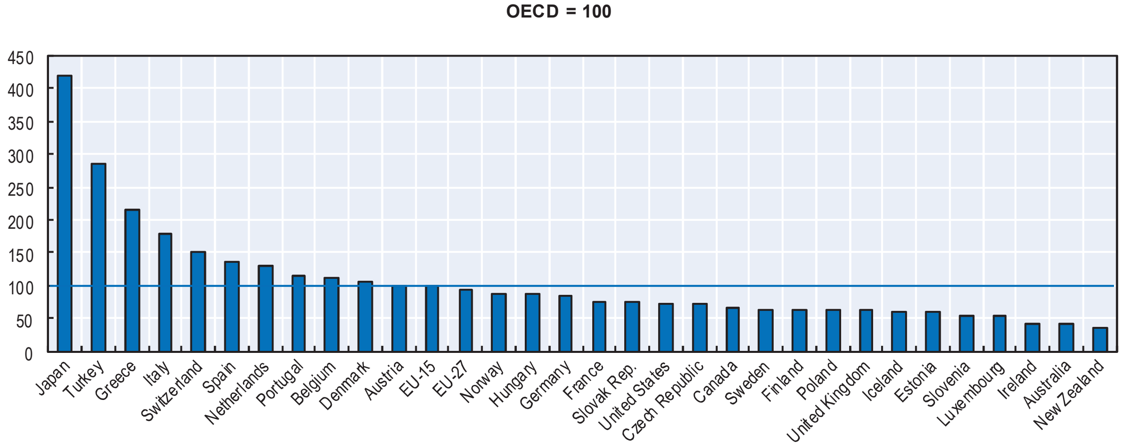
Figure 3.6. Agricultural economic growth and GHG emissions and relation with decoupling, 1990-2010



Note: Carbon productivity is the agricultural GDP per unit of agricultural GHG emissions.
Source: UNFCCC *Greenhouse Gas Inventory Data*, http://unfccc.int/ghg_data/items/3800.php; FAO, *FAOSTAT* (database), http://faostat.fao.org/.

StatLink http://dx.doi.org/10.1787/888933144600

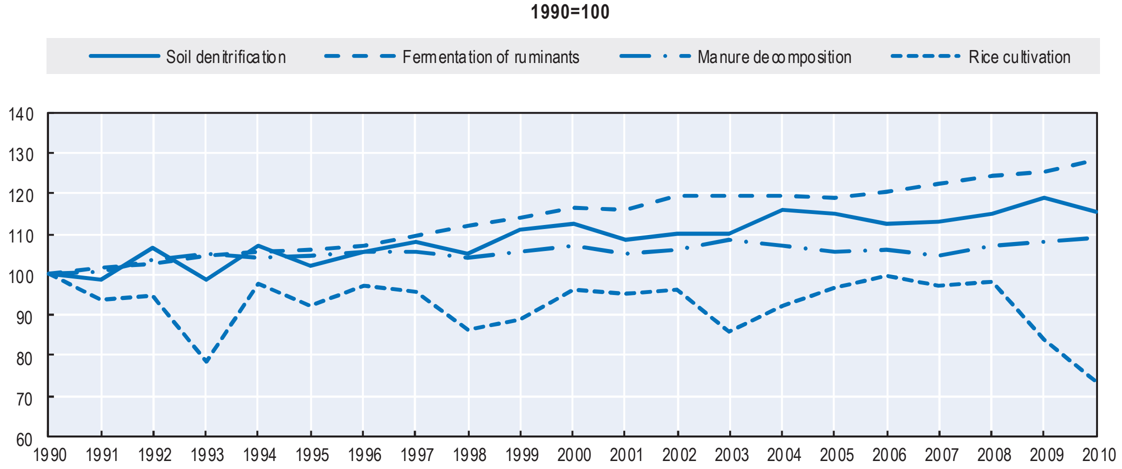
Figure 3.7. Agricultural GHG emissions productivity, 2008-10



Note: Excluding LULUCF (land use, land use-change and forestry).
Source: UNFCCC *Greenhouse Gas Inventory Data*, http://unfccc.int/ghg_data/items/3800.php.

StatLink http://dx.doi.org/10.1787/888933144617

Figure 3.8. Agricultural GHG emissions productivity by source in the OECD area



Note: Excluding LULUCF (land use, land use-change and forestry).

Source: UNFCCC *Greenhouse Gas Inventory Data*, http://unfccc.int/ghg_data/items/3800.php; FAO, *FAOSTAT* (database), http://faostat.fao.org/.

StatLink http://dx.doi.org/10.1787/888933144626

Energy productivity

Policy context

Energy is a key requirement to achieve competitiveness and sustainability in the agricultural sector. The links between agriculture and energy are complex, as agriculture is both a consumer and a producer of energy. Farming consumes energy directly through the use of machinery (e.g. operating machinery and equipment), and the heating of stables and greenhouses, and also consumes energy indirectly, in terms of the energy required to produce fertilisers, pesticides, farm machinery and other inputs. But agriculture is also an important potential source of clean, renewable energy.

Support to agricultural energy use is widespread across OECD countries, mainly through reduced standard rates of fuel tax for on-farm consumption. Support is also common across the OECD area for bioenergy through the provision of a combination of tax incentives and payments for bioenergy production, feedstocks using agricultural raw materials (e.g. maize), and waste (e.g. straw).

The key challenge is to improve energy use efficiency on-farm by lowering the energy consumption per unit of agricultural production and to seek opportunities to increase the production of environmentally neutral biofuel feedstocks (i.e. requiring less energy to produce than the energy generated and having minimal impact in terms of water pollution and air pollution).

Monitoring progress

Progress towards green growth can be assessed against: i) the energy productivity of agriculture (the ratio of agricultural GDP per unit of direct use of energy (solid fuels, oil, gas, electricity, renewables, heat and industrial waste);[2] and ii) trends in the volume of renewable energy produced by agriculture.

These indicators should be studied in conjunction with those concerning GHG emission productivity, R&D and patents related to energy efficiency and renewable energy, energy prices and taxes, and carbon pricing and biofuel support.

Measurability

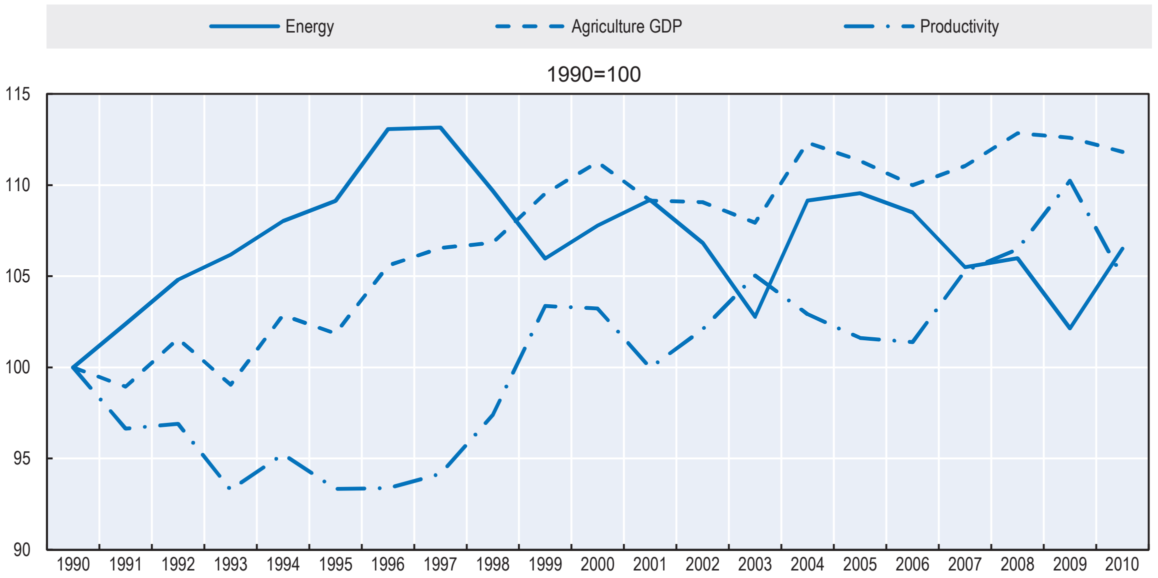
Data on energy productivity pertain to direct on-farm energy consumption by primary agriculture, which includes energy consumption for: electricity, heating fuel and machinery fuel used in crop production; grain drying, animal production; poultry; transportation of farm products and personal use (for example, heating the farmhouse and driving to town). Indirect use of energy (i.e. energy consumed in the production, packaging and transport to the farm gate of fertilisers, pesticides, farm machinery and buildings) is not included. Data also cover energy used in forestry, which is assumed to be insignificant in most countries relative to agriculture.[3]

Comprehensive data on renewable energy produced by agriculture are not readily available and are not reported here.

Main trends

Across the OECD area, energy use in agriculture increased over the 1990-2000, on average, at a higher rate than agricultural GDP, suggesting that a relative decoupling took place. This trend was reversed in 2000 and onwards, with absolute decoupling as the growth rate in agricultural production outpaced growth in energy productivity, although differences between OECD countries in energy productivity remain high (**Figure 3.9** and **3.10**).

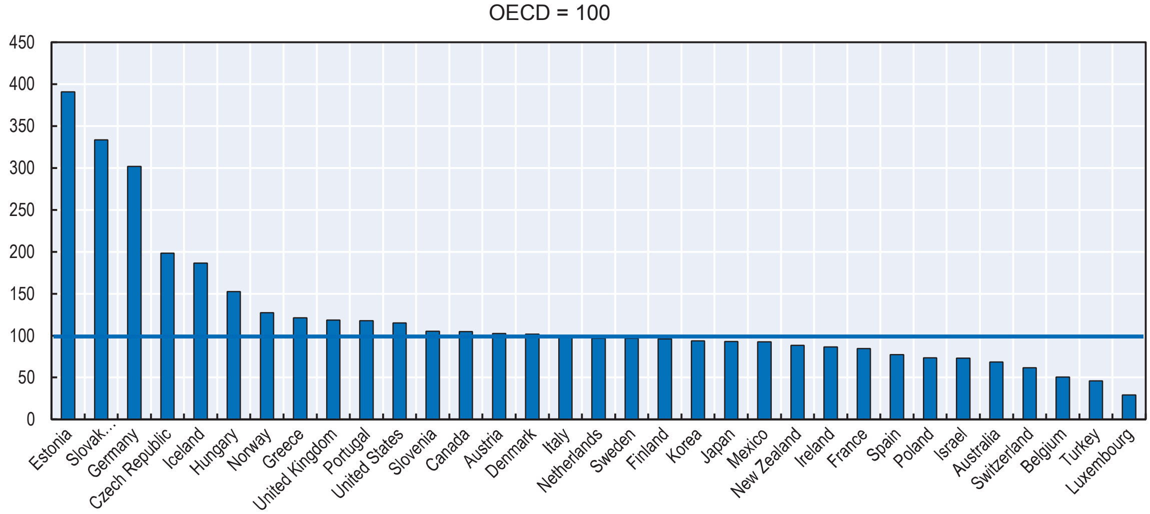
Figure 3.9. Direct on-farm energy productivity, OECD area



Source: UNFCCC *Greenhouse Gas Inventory Data*, http://unfccc.int/ghg_data/items/3800.php; FAO, *FAOSTAT* (database), http://faostat.fao.org/.

StatLink http://dx.doi.org/10.1787/888933144631

Figure 3.10. Direct on-farm energy productivity, 2009-10



Source: UNFCCC *Greenhouse Gas Inventory Data*, http://unfccc.int/ghg_data/items/3800.php; FAO, *FAOSTAT* (database), http://faostat.fao.org/.

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Water use intensity

Policy context

Farming accounts for around 70% of the water used in the world today (45% in the OECD area) and if no new policies are put in place, demand for water in agriculture could rise by over 30% by 2050. Increased pressure from urbanisation, industrialisation and climate change will provide agriculture with more competition for water resources. Several OECD countries, particularly those which face scarcity of water resources, have policy strategies to address water management in agriculture (OECD, 2010).

Monitoring progress

The indicator proposed relates to trends in irrigation water per hectare of irrigated area. The share of irrigated area in total agricultural area is proposed as a supplemental indicator. Both indicators should be analysed along with indicators on available renewable freshwater resources and indicators on water abstractions by major use (OECD, 2014).

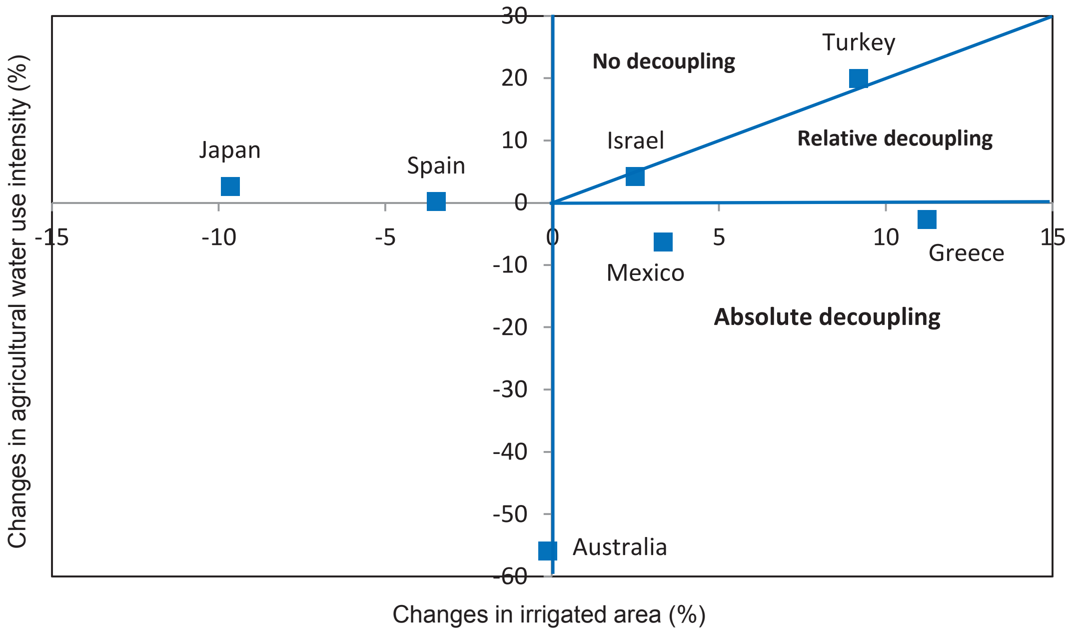
These two indicators have a number of limitations which must be taken into account when examining absolute levels and trends when comparisons across countries are made (OECD, 2013). In particular, complete and consistent time-series data are available for only a handful of OECD countries (**Figure 3.11**), partly because these data are not usually calculated annually but are derived from five- or even ten-year surveys.

Methods of collecting and calculating the data vary across and within countries and are subject to errors of measurement. Sources of data for irrigation freshwater withdrawals include sample surveys of irrigators, and are sometimes estimated using information on irrigated crop acreages along with specific crop water-consumption coefficients or irrigation-system application rates. In other cases, irrigation water withdrawal data may reflect water allocations, which may differ substantially from actual withdrawals depending on annual climatic conditions (OECD, 2013).

The term "agricultural water withdrawals" refers to "water abstractions" for irrigation and other agricultural withdrawals (such as for livestock) from rivers, lakes, reservoirs and groundwater (shallow wells and deep aquifers), and "return flows" from irrigation, but excludes precipitation directly onto agricultural land. "Water withdrawal" is different from "water consumption", which relates to water depleted and not available for re-use.

In some OECD countries, irrigated agriculture accounts for a significant share of agricultural water withdrawals. Overall, the total OECD area irrigated decreased over the 2000s at -0.4% per annum, compared to a slight increase during the 1990s (OECD, 2013). The reduction in the area irrigated in the last decade largely reflects decreases reported in Australia, Japan, Italy, Greece and Spain (**Figure 3.12)**. Reductions in agricultural production, improvements in efficiency with the remaining areas irrigated and prolonged drought in some regions are main reasons for the decline in irrigated area.

Figure 3.11. Agricultural water use intensity versus irrigated area

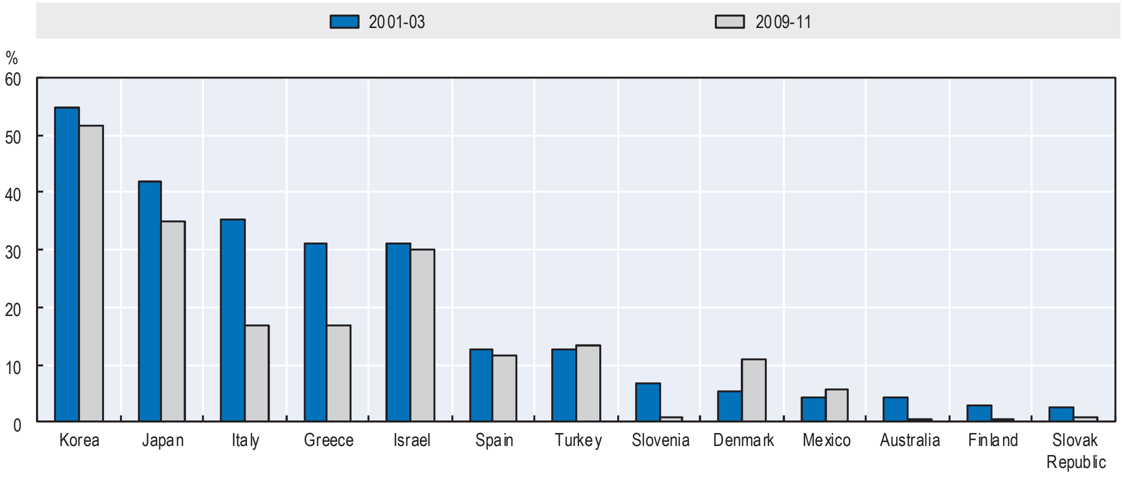


Note: Agricultural water use intensity is defined as irrigation water per irrigated area. Changes refer to the average of 2005-10 and 1990-95.

Source: OECD (2013), "Agri-Environmental Indicators: Environmental Performance of Agriculture 2013", *OECD Agriculture Statistics* (database).
doi: 10.1787/data-00660-en.

StatLink http://dx.doi.org/10.1787/888933144654

Figure 3.12. Share of irrigated area



Note: Korea 2007 instead of 2009-11.

Source: World Bank, *World Development Indicators (database)*, http://data.worldbank.org/data-catalog/world-development-indicators.

StatLink http://dx.doi.org/10.1787/888933144666

Nutrient flows and balances

Policy context

Nutrients, such as nitrogen, phosphate and potash, are essential to maintain and raise crop and forage productivity. Most of these nutrients, which are applied annually, are absorbed by crops; however, when applied in excess that which is not absorbed can volatise into the environment, leach into the groundwater, be emitted from soil to air, or runoff into the surface water. Where there is a deficit in nutrients, soil fertility can decline, while an excess of nutrients entails the risk of polluting soil, air and water through eutrophication.

Across the OECD area there is a widespread incidence of surplus nutrient application and nearly all OECD countries, to varying degrees, apply an extensive range of policy instruments (payments, taxes, regulations, farm advice, etc.) to address nutrient pollution of water and air in terms of ammonia emissions (OECD, 2013). The challenge is to seek ways to increase production while minimising farm nutrient losses and subsequent damage to the environment.

Monitoring progress

Two types of indicators are proposed: i) changes in agricultural nutrient balances and intensities and; ii) changes in intensities of inorganic (commercial) fertilisers. More specifically, the proposed indicators are:

- Changes in nitrogen (N) intensity (gross N balance per ha of agricultural land) related to changes in agricultural production.
- Changes in phosphorus (P) intensity (gross P balance per ha of agricultural land) related to changes in agricultural production.
- Changes in commercial fertiliser intensities, calculated by dividing the annual consumption of commercial fertilisers with the area of arable land.

These indicators are proxies of the risk of environmental pressures associated with agricultural production: declining soil fertility (in the case of a nutrient deficit) or the risk of soil/water/air pollution (in the case of a nutrient surplus). Nutrient balances and intensities provide an indication of the level of potential environmental pressures from nutrients, in particular on soil, water and air quality in the absence of effective pollution abatement.

It should be noted that these indicators describe potential environmental pressures and may hide important sub-national variations. Cross-country comparisons of change in nutrient surplus intensities over time should take into account the absolute intensity levels during the reference period. Any analysis must take into account information on agricultural land use and farm management approaches.

Measurability

The gross nutrient balances (N and P) are calculated as the difference between the total quantity of nutrient inputs entering an agricultural system (mainly fertilisers and livestock manure), and the quantity of nutrient outputs leaving the system (mainly uptake of nutrients by crops and grassland).

Nutrient balances are expressed in terms of changes in the physical quantities of nutrient surpluses (deficits) to indicate the trend and level of the potential physical pressure of nutrient surpluses into the environment. The nutrient balance indicator is also expressed in terms of kilogrammes of nutrient surplus (deficit) per hectare of agricultural land per annum to facilitate the comparison between countries of the relative intensity of nutrients in agricultural systems.

Data on nitrogen and phosphorus balances are available for almost all OECD countries from 1990 to 2009 (OECD, 2013). Data on apparent consumption of commercial fertilisers are published by the International Fertiliser Industry Association (IFA) and the FAO.

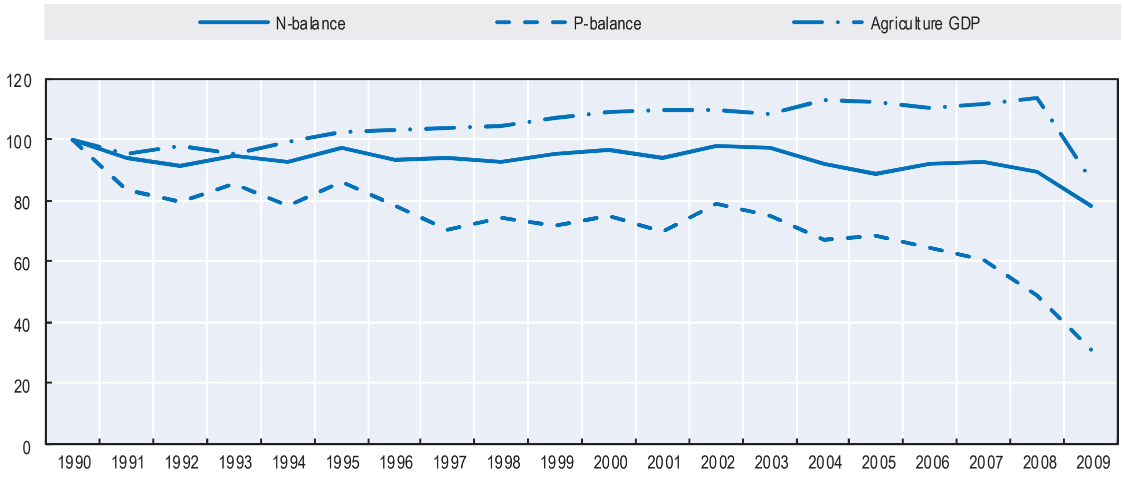
Main trends

For many OECD countries, nutrient surpluses have been declining over time relative to agricultural output. Overall, OECD agricultural surpluses N and P have been on a continuous downward trend from 1990 to 2009, both in absolute tonnes of nutrients and in terms of nutrient surpluses per hectare of agricultural land. The rate of reduction in nutrient surpluses in the OECD area was more rapid over the 2000s compared to the 1990s, signalling a process of relative decoupling of agricultural production from N- and P-related environmental pressure (**Figure 3.13** and **Figure 3.14**).

A similar picture emerges from the trends in inorganic fertiliser intensities, particularly since 2000; their consumption has been trending downwards, while crop production has been increasing (**Figure 3.15** and **Figure 3.16)**.

These developments reflect both improvements in nutrient use efficiency by farmers and slower growth in agricultural output in many countries. The lowering of nutrient surpluses has reduced the risk of environmental pressure on soil, water and air, but sizable variations within and across countries in terms of the intensity and trends of nutrient surpluses indicate various degrees of decoupling.

Figure 3.13. Nutrient balances intensity and agricultural production
OECD area (1990=100)

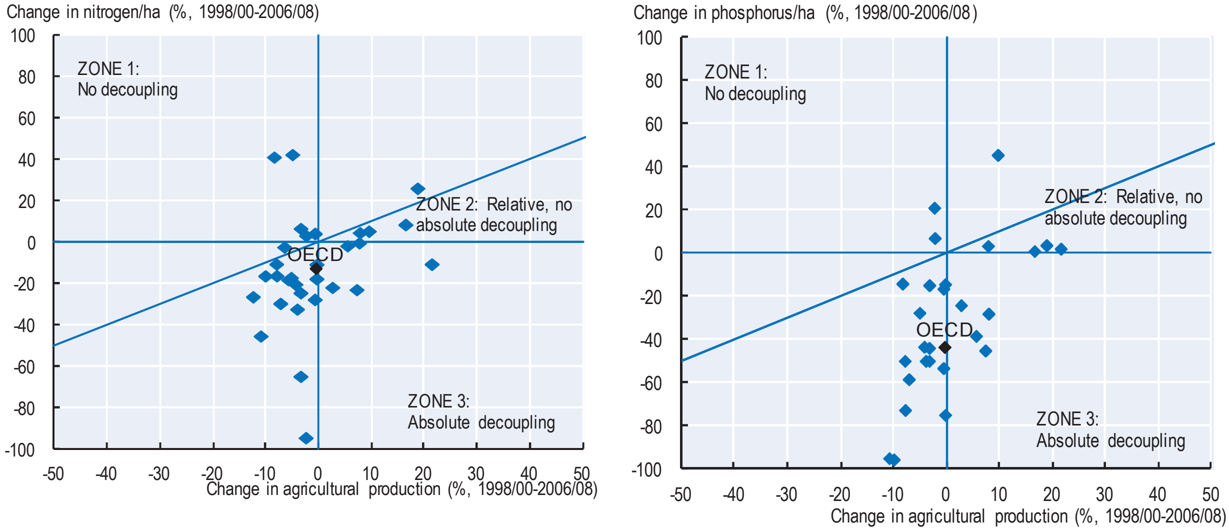


Note: Nutrient balance intensity is defined as the balance (surplus or deficit) of nitrogen and phosphorus per hectare of agricultural land.

Source: OECD (2013), "Agri-Environmental Indicators: Environmental Performance of Agriculture 2013", *OECD Agriculture Statistics* (database).
doi: 10.1787/data-00660-en.

StatLink http://dx.doi.org/10.1787/888933144677

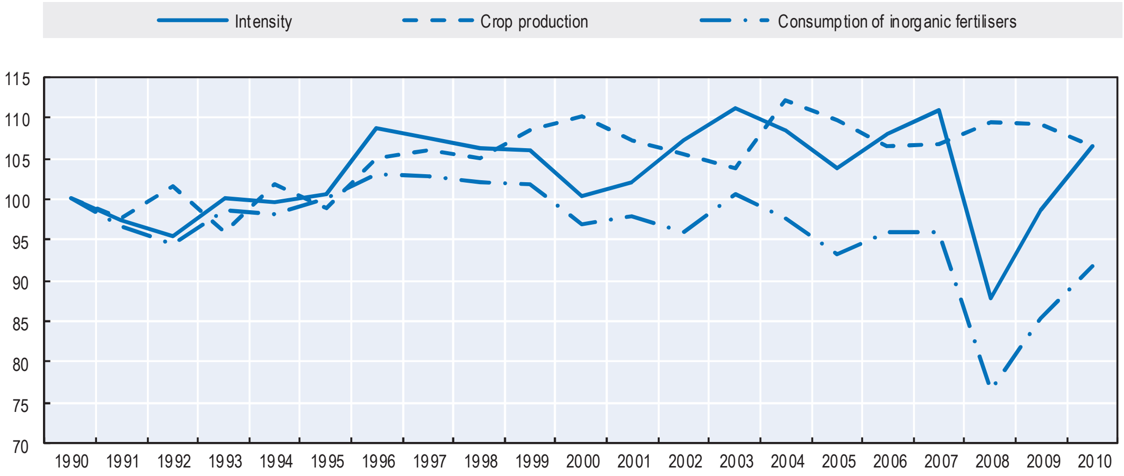
Figure 3.14. Nutrient decoupling trends



Source: OECD (2014), Decoupling trends: agricultural nutrient balances and agricultural production, in *Green Growth Indicators 2014*, OECD Publishing.
doi: 10.1787/9789264202030-graph25-en.

StatLink http://dx.doi.org/10.1787/888933144686

Figure 3.15. Apparent consumption and intensity of inorganic fertilisers, and crop production, OECD area

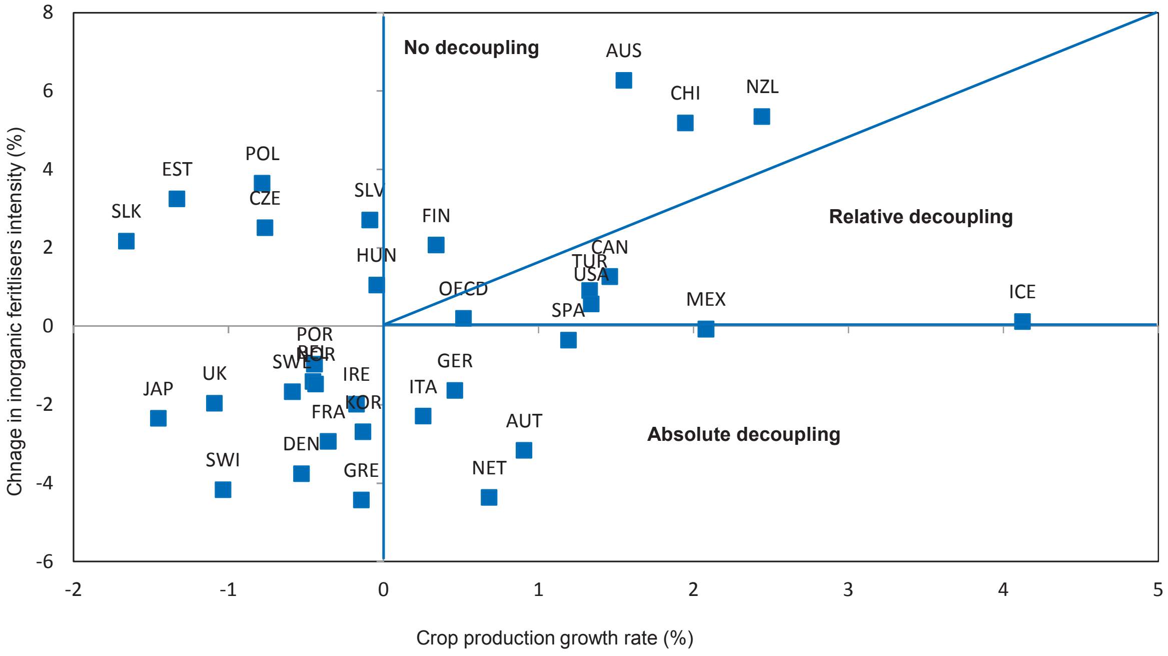


Note: Intensity of inorganic fertiliser is defined as the annual consumption of commercial fertilisers per hectare of arable land.

Source: FAO, *FAOSTAT* (database), http://faostat.fao.org/; International Fertiliser Association (IFA), *IFADATA* (database), http://www.fertilizer.org/Statistics.

StatLink http://dx.doi.org/10.1787/888933144690

Figure 3.16. Decoupling trends of inorganic fertilisers



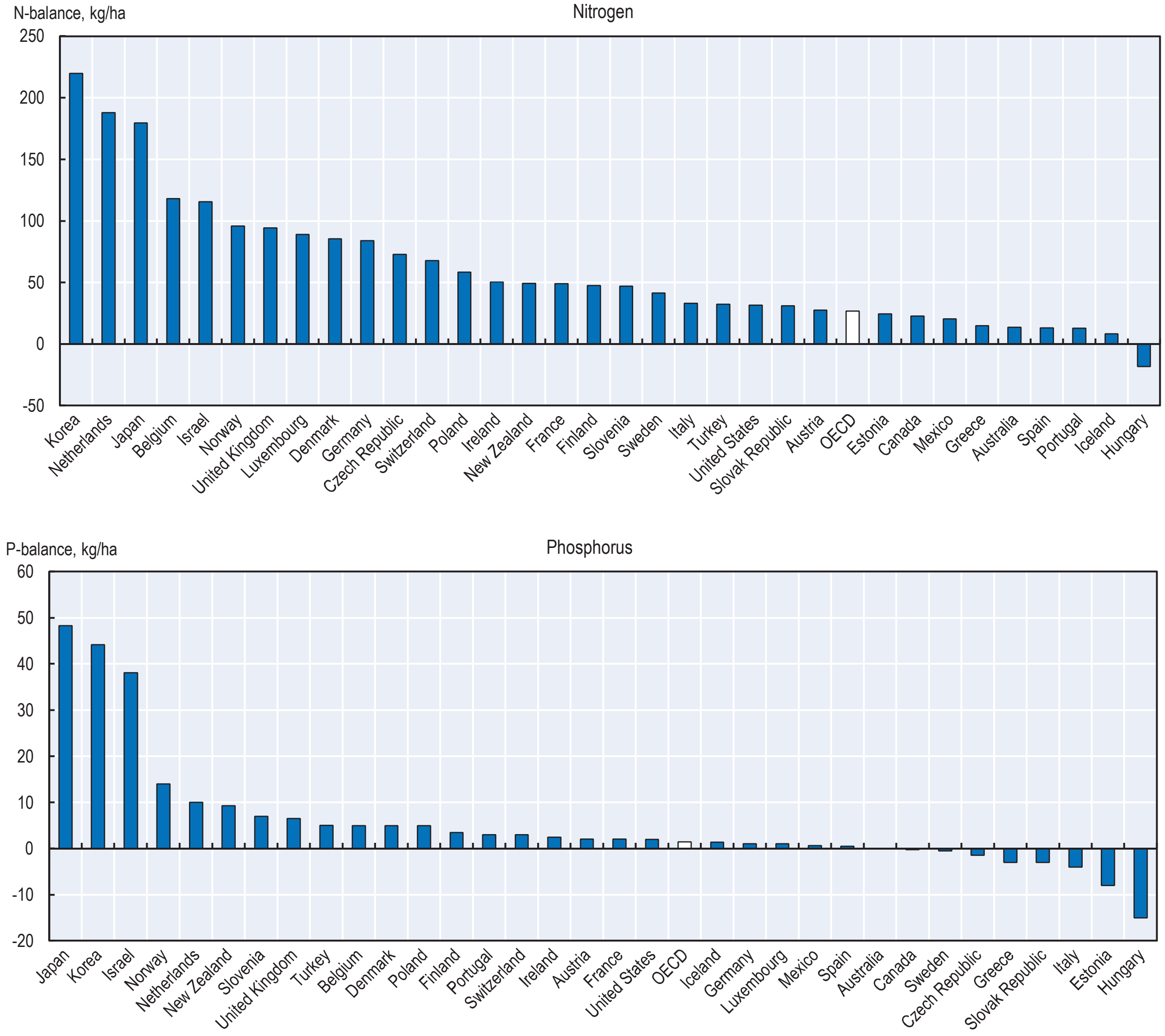
Note: Changes relate to 1990-2010.

Source: FAO, *FAOSTAT* (database), http://faostat.fao.org/; International Fertiliser Association (IFA), *IFADATA* (database), http://www.fertilizer.org/Statistics.

StatLink http://dx.doi.org/10.1787/888933144700

Despite the overall improvement in lowering nutrient surpluses, nitrogen and phosphorus intensity levels per hectare of agricultural land remain at very high levels in terms of their potential to cause environmental damage. By 2008-09, around two-thirds of OECD countries had an annual national nitrogen surplus in excess of 40 kgN/ha nitrogen, with Belgium, Israel, Japan, Korea and the Netherlands reporting surpluses in excess of 100 kgN/ha (**Figure 3.17**). Similarly for phosphorus, about one-third of OECD countries had a surplus in excess of 5 kgP/ha, over the same period, with Israel, Japan, Korea, the Netherlands, and Norway, having surpluses in excess of 10 kgP/ha.

Figure 3.17. Nutrient intensities per area of agricultural land, 2008-09 (kg/ha)



Source: OECD (2013), "Agri-Environmental Indicators: Environmental Performance of Agriculture 2013", *OECD Agriculture Statistics* (database).
DOI: 10.1787/data-00660-en.

StatLink http://dx.doi.org/10.1787/888933144711

Material productivity (biomass)

Policy context

Resource productivity and efficiency are high on the international policy agenda and are the focus of several national and international initiatives, such as the Kobe 3R Action Plan, the UNEP International Resource Panel and the EU 2020 Flagship initiative on resource efficiency. The OECD has two Council Recommendations related to advancing work in this area.

Monitoring progress

Monitoring natural resources – the way they are used in economic activity and contribute to economic outputs – and how their use impacts on the environment requires comprehensive data on natural resource flows and indicators that monitor progress.

Indicators based on Material Flows Analysis[4] are useful to measure progress with resource productivity. They also provide insights into the economic efficiency and environmental effectiveness with which materials are used in the production and consumption chain up to final disposal. A commonly used indicator is material productivity (or intensity), relating economic output to the amount of materials (or raw materials) used as inputs. It is defined as GDP per Domestic Material Consumption (DMC) or per Domestic Material Input (DMI).[5] It can be derived from Economy-Wide Material Flow Accounts[6] that cover the economy as a whole and distinguish between various material types and groups. Water as a resource is not covered in such accounts and needs to be reported separately.

Applying this approach to agriculture would require data on material flows broken down by industry, or alternatively data on major material inputs into agricultural activity and on material outputs from agricultural activity, including processed products. Such data are not yet available for all OECD countries and relevant indicators have yet to be defined.

Environmentally adjusted total factor productivity

Policy context

Central to examining green growth in agriculture is the inclusion of environmental externalities in growth accounting. Agricultural production affects natural resources and influences eco-systems and biodiversity. Many of these environmental effects exhibit the characteristics of negative or positive externalities or public goods, for which private markets do not exist or are poorly functioning. These effects are usually neglected in traditional growth accounting frameworks or in estimations of common indicators of economic performance, such as total factor productivity (TFP). By omitting these developments, traditional TFP – which is often interpreted as a measure of economic efficiency, competitiveness and a long-term determinant of material living standards – may be biased and lead to incorrect policy conclusions. Some of these problems can be addressed by developing a measure of total factor productivity that is adjusted for the use of natural resources and other environmental services.

Monitoring progress

As noted earlier, TFP is a well-defined measure of productivity but is usually computed as a residual and thus more difficult to communicate than partial productivity measures, such as labour productivity. Accounting for natural resource inputs and for emissions such as negative outputs would add an additional element of complexity. Nevertheless, this is considered to be a conceptually correct way of examining measurement bias that may arise from not recognising environmental services in traditional TFP measures.

Measurability

This indicator is not currently measurable and the OECD is researching ways to advance work in computing this indicator. The objective is to examine whether TFP growth has been under- or overstated as a consequence of omitting undesired outputs and natural resource inputs from the calculation (**Box 3.3**). The work will begin by focusing on integrating natural resources, such as land, timber, and sub-soil resources, into a set of inputs and on integrating undesirable outputs (selected emissions) into the set of outputs. OECD has also begun exploratory work on calculating environmentally-adjusted TFP for the agricultural and energy sectors.

Box 3.3. OECD's on-going work on adjusting total factor productivity estimates to account for environmental services

The OECD has developed a calculation method for adjusting TFP estimates to account for environmental services and applied it to selected countries. The work is based on the literature on productivity measurement with undesirable outputs (Pittman, 1983; Repetto et al. 1997). It integrates selected natural resources (land, timber, subsoil assets) as input factors and selected pollutant emissions (carbon dioxide, sulphur and nitrogen oxides) as undesirable "bad" outputs in the production function. The absence of data on resources, such as water and fish stocks, precludes their inclusion in the analysis at this stage.

The framework is based on a standard production function, whereby output is derived using labour and capital input factors. This function is complemented by natural capital and the negative effect of undesirable bad output on production. Two adjustments are made to the standard production function. First, natural capital inputs (including minerals, oil, gas, coal and timber) are aggregated into a natural resource index and enter the production function as a third input factor. Second, "bad outputs", essentially air pollutants, such as sulphur oxides and nitrogen oxides and CO_2 emissions are added to output to derive effective output.

The biggest challenge is data availability regarding the use of environmental inputs in production and the associated costs, in particular the cost of the depletion and degradation of natural resources and their use in consumption and production. As a first step, the techniques to compute the monetary value of natural resources are consistent with the 2008 SNA and the 2012 Central Framework of the SEEA. No attempt is made to estimate the value of other environmental services, particularly for "non-uses" such as regulating services. The SEEA Experimental Ecosystem Accounts will, in the longer term, provide further guidance on techniques for valuations.

Although subject to limitations in its practical implementation, this extension of productivity measurement can allow for a more accurate assessment of economic performance. Preliminary results of the OECD's work show that the adjustment of the traditional productivity growth measure for bad outputs is small. While this partly hinges on the fact that for lack of more comprehensive data only a limited set of bad outputs were considered – namely carbon dioxide, sulphur and nitrogen oxides – the relatively small adjustment of the traditional productivity growth measure is good news for two reasons. First, it implies that ignoring the bad outputs considered in this paper results in a relatively small bias of productivity measurement, and thus analysis based on traditional measures should be relatively reliable in this regard. Second, it also implies that the acceleration in productivity growth that would help to substantially reduce the bad outputs considered, without reducing output growth, should be possible to achieve.

Source: Brandt, N., P. Schreyer and V. Zipperer (2014), "Productivity Measurement with Natural Capital and Bad Output", *OECD Economics Department Working Papers*, No. 1154, OECD Publishing, Paris.

Notes

1. Agricultural GDP refers to gross agricultural production value in constant 2004-06 USD as reported in FAOSTAT.
2. Agricultural GDP refers to gross agricultural production value in constant 2004-06 USD as reported in FAOSTAT.
3. The *Life+ Agriclimatechange* project aims to develop a software tool to assess energy consumption and GHG emissions (*htwww.agriclimatechange.eu/index.php?lang=en*). This comprehensive tool is intended to be applicable throughout the whole of the European Union and was implemented between September 2010 and December 2013. Action plans were designed and implemented for farms located in the four participating countries (France, Germany, Italy and Spain).

4. Material Flow Analysis (MFA) studies how natural resources and materials flows into, through and out of a given system (usually the economy) and how these flows interact with the economy and the environment. It is based on methodically organised physical flow accounts that provide data on the material inputs taken from the environment into the economy (e.g. resources extracted or harvested from the surrounding natural environment or imported from other countries), the transformation and use of inputs within the economy (from production to final consumption) and the material outputs from the economy to the environment as residuals (waste, pollutants) or to other countries in the form of exports. The data are compiled from available production, consumption and trade data, and from environment statistics (on waste, emissions, etc.).

5. DMI measure the material inputs into an economy, accounting for the domestic extraction of materials and imports. DMC measures the amount of materials consumed in an economy (i.e. the direct apparent consumption of materials). It is composed of two elements, namely the domestic extraction and the physical trade balance (which equals imports minus exports). DMC equals DMI minus exports.

6. MF accounts are part of the family of physical flow accounts described in the Central Framework of the System of Environmental Economic Accounts (SEEA). The SEEA has been adopted as an international statistical standard (UN, 2014). The reporting on economy-wide MF is mandatory in the European Union.

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From:

Green Growth Indicators for Agriculture

A Preliminary Assessment

Access the complete publication at:

https://doi.org/10.1787/9789264223202-en

Please cite this chapter as:

OECD (2014), “Monitoring the environmental efficiency and natural resource productivity of agriculture”, in *Green Growth Indicators for Agriculture: A Preliminary Assessment*, OECD Publishing, Paris.

DOI: https://doi.org/10.1787/9789264223202-7-en