

GRAPE documentation v1.0.0

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Introduction

As described in the main document, for most countries the agricultural R&D expenditure and number of researcher series were constructed by combining data from several international datasets (e.g. ASTI, EUROSTAT and OECD), national statistics and (grey) literature sources. The main GRAPE data file includes a column *source*, which presents a reference to the source for each observation. The full reference list is presented at the bottom of this document. For several countries, we introduced major updates or constructed completely new series. This document presents detailed information on how these new estimates and updates were constructed for each country. In addition, it describes the country-specific decisions to handle extreme values that were observed in some data sources and post-imputation adjustments to deal with outliers that were not consistent with historical trends. These adjustments as well as approaches used to impute missing information were given a code in the main GRAPE data file (*pre_processing* and *linking* columns), which explanation is also presented below. Finally, this document also lists the countries for which we identified data for pre-1960, which were also added to the dataset.

Country documentation

American Samoa (ASM), Guam (GUM), Marshall Islands (MHL), Micronesia (FMS), Northern Mariana Islands (MNP), Palau (PLW), Puerto Rico (PRI), U.S. Virgin Islands (VIR)

Public agricultural R&D spending in these United States insular territories through 2001 were taken from the research reporting systems of the National Institute of Food and Agriculture (NIFA), U.S. Department of Agriculture. Through 2001, these were given in the annual reports of the Current Research Inventory System

(CRIS). From 2002 onward, data were taken from the National Institute of Food and Agriculture online Data Gateway system (<https://www.nifa.usda.gov/data/data-gateway>).

Angola (AGO)

FAO (2024) provided GBARD data for the period 2001-18. The estimate for 2001, which coincided with the final years of the civil war, was considered unrealistically high in comparison with the data from (Pardey et al., 1991), which covered the period up to the start of the war in the mid-1970s. The imputation seemed to capture the impact of war reasonably well and was therefore preferred.

Australia (AUS)

The number of researchers data from OECD (2024) before 2002 was extremely low in comparison to information from Pardey et al. (1991) and therefore dropped.

Burundi (BDI)

We disregarded FAO (2024) GBARD data, which showed an implausibly steep increase between 2015-16 in comparison to the ASTI (2024) series.

Canada (CAN)

Canada is a country for which public agricultural, forestry, and fisheries (AFF) research is funded at both the federal and provincial levels but the federal government has historically dominated funding. Performance has increasingly moved to non-federal institutions (primarily higher education) in recent years until federal and non-federal performance levels are roughly equal. Canada was an early leader in science and technology (S&T) statistics (Godin, 2005), and a wealth of data are available, but for our purposes they very often concern federal estimates only. Care must also be taken with Canadian data as they are frequently presented in terms of S&T, which is a broader category than research and development (R&D). All past estimates of Canadian AFF R&D have begun with similar information on federal intramural and extramural research expenditures.

Updating R&D expenditure for Canada follows Heisey et al. (2018) with the following important changes:

- The update follows Pardey et al. (1989) and Pardey et al. (1999) through 1993, rather than using slightly different calculations to estimate non-Federal funding from 1981-93. The differences between Pardey et al. (1999) and Heisey et al. (2018) for these years are small.
- For provincial agricultural R&D funding the update follows the Agriculture Canada data books for all provinces up through either 2014 or 2017, rather than using a hybrid of Agriculture Canada and Statistics Canada sources as Heisey et al. (2018). This is because the Agriculture Canada data books cover all provinces, in particular including Quebec, and because they are available with information through 2017. Detailed Statistics Canada information on AFF R&D in some, but not all, provinces only runs through 2010.
- Estimates for provincial funding of forestry research are confined in the update to the four provinces with significant investment in this research—British Columbia, Alberta, Ontario, and Quebec. Provincial funding of forestry research in some of the other provinces is quite small, and the evidence is highly fragmentary.

- No estimates are made for provincial funding of fisheries research in the update. Although there is very limited provincial funding of fisheries research, it is quite small and again, the evidence is fragmentary.

Updating provincial funding estimates through 2022 for both agriculture and forestry (in the provinces named above) was done primarily by searching for direct estimates of investment, of which there are few. For the most part, however, provincial funding estimates were constructed using ministry budgets or line items within those budgets that could be related to earlier estimates when information was available for overlapping years. In a few cases direct comparisons could be made; more often provincial R&D funding was estimated based on assumed percentages of budget figures.

We constructed a R&D personnel series from the late 1970s to 2024. Estimates for Agriculture Canada and Fisheries and Oceans Canada research personnel are available from various Statistics Canada sources, and estimates for the Canadian Forestry Service can also be inferred from these sources. More problematic are estimates for Federal R&D personnel performing AFF R&D outside these three major institutions (only evident in the last 20 years), and estimates for higher education and provincial government AFF researchers are even more constrained. We used our own R&D expenditure data and Statistics Canada data on sectoral R&D personnel to approximate these counts. We combined our research personnel series with data from Pardey et al. (1989) (1977-65) and Pardey et al. (1991) (1961-64) to extend the series backwards to the early 1960s.

China (CHN)

Public agricultural R&D expenditure were taken from Fan et al. (1992) (1953-61), Fan, Qian, et al. (2006) (1962-79), Chai et al. (2019) (1980-2002) and various issues of the China Statistical Yearbook on Science and Technology (2002-20). It should be noted that the agricultural R&D investment data in China represents the sum of R&D expenditures across all agriculture-related fields. For research institutions, the agriculture-related industries include agriculture, forestry, animal husbandry, fisheries, services for agriculture, forestry, animal husbandry and fisheries, agricultural and sideline food processing, food manufacturing, and water conservancy management. For higher education, the agriculture-related disciplines include biology, agronomy, forestry, animal husbandry and veterinary science, aquaculture, food science, and hydraulic engineering.

Information on the number of public agricultural researchers was obtained from Fan et al. (1992) (1960-87), Fan, Qian, et al. (2006) (1988-2002) and various issues of the China Statistical Yearbook on Science and Technology (2002-20). There was a definition change in 2009. The 2002-2008 personnel figures from the Statistical Yearbook refer to ‘science & technology’ (S&T) while the 2009-20 figures are more narrowly defined as ‘research and development’ (R&D) researchers. There were no overlapping years with the two series to indicate the share of S&T personnel who are classified as R&D personnel. We decided to take the average R&D/S&T expenditure ratio over 2002-08 (62%) and applied this to the S&T personnel figures to get R&D personnel for these years. Personnel data in Fan et al. (1992) and Fan, Qian, et al. (2006) used the S&T definition. We assumed that the growth rates of S&T and R&D personnel was the same and used S&T growth rates to backcast the R&D series from the Statistical Handbook. We only used S&T researcher data for the period 1988-2002 from Fan, Qian, et al. (2006) as for unknown reasons the older figures were implausibly high and not in line with the data presented in Fan et al. (1992), which we considered as more reliable.

Colombia (COL)

We disregard public agricultural R&D expenditure information provided in OECD (2024) for the period 2016-20, which was extremely low in comparison to estimates from ASTI (2024). In Colombia, most public agricultural R&D spending is financed through commodity levies, which were most likely not captured by the OECD (2024) figures.

Ecuador (ECU)

Public agricultural R&D expenditure data for the period 1961-97 were taken from Pardey et al. (1989) (1961-86) and Morales (1998) for (1990-97). Intermediate years were imputed using the growth rate in number of researchers, also from Morales (1998). The GDP deflator price index the World Development Indicators [World Bank2024] understated the inflation in Ecuador in Sucre prior to their dollar conversion in 2000. To account for this, Sucre were first converted into USD 1980 PPP values using the PPP conversion factor in Pardey et al. (1989) and then converted to USD 2017 PPP values using the US GDP deflator.

Egypt (EGY)

The Egyptian R&D expenditure series were developed by splicing together data from Pardey et al. (1989) for the period 1960-84 and unpublished data used in Fan, Al-Riffai, et al. (2006) for the period 1980-98. These series were combined with information from ASTI (2024) for 2009-12 and extrapolated with GBARD data from FAO (2024), which were available from 2013 onward.

El Salvador (SLV)

We disregarded FAO (2024) GBARD data, which shows an implausibly steep increase between 2019-2020 in comparison to the ASTI (2024) and UNESCO (2021) R&D expenditure series.

France (FRA)

Public agricultural R&D spending in France was the sum of annual spending by the National Research Institute for Agriculture, Food and Environment (INRAE) and the Federation of Agricultural Technical Centers (ACTA). We also included INRAE's predecessor institutes, the National Research Institute for Agronomy (INRA) and the National Research Institute for Science and Technology for Environment and Agriculture (IRSTEA). In 2020, INRA and IRSTEA were merged to form INRAE. INRA annual spending from 1946 to 2013 are available in Lemarié et al. (2020). INRA/INRAE estimates were extended beyond 2013 from the annual reports of these institutes. Agricultural R&D spending by IRSTEA were available for 1969 and 1985 from Pardey et al. (1989) and from 1998 to 2019 from IRSTEA annual reports. Annual R&D spending by ACTA were available for 1985 from Pardey et al. (1989) and from ACTA annual reports for 2007, 2014, and 2021. Estimates of IRSTEA and ACTA spending for missing years were interpolated assume a constant rate of annual growth.

Indonesia (IDN)

Public agricultural R&D in Indonesia included spending by the Agency for Agriculture Research and Development (AARD), the Indonesian Institute for Estate Crops (IRIEC), the Forestry Research and

Development Agency (FORDA), and by universities. Estimates of Public agricultural R&D spending in Indonesia for 1967-73 were taken from Van der Eng (1996). Fuglie@2006a provided estimates for 1974 to 1999. For years 2000 and onward, estimates were from ASTI. For 1960 to 1966, we assumed that annual spending for agricultural R&D was USD 7.5 million (constant 2017 PPP\$), converted from Van der Eng's estimate of 99 million Rupiah for 1967.

Kenya (KEN)

We disregarded FAO (2024) GBARD data, which shows an implausibly steep decline between 2014-22 in comparison to the ASTI (2024) R&D expenditure series.

Kyrgyzstan (KGZ)

We corrected the R&D expenditure value for 2018 in FAO (2024) that was used to splice together the FAO (2024) and UNESCO (2021) data series. The observation was a factor 10 times too low and, hence, most likely a data entry error.

Mauritania (MRT)

We disregarded the R&D expenditure data from UNESCO (2021), which showed an implausibly steep decline between 2016-18 in comparison to the ASTI (2024) series.

Montserrat (MSR)

Data on agricultural GDP were not available from United Nations (2024) for recent years, which made ensemble imputation impossible. We assumed that R&D expenditure and number of researcher data remained constant since the last observation (1981) from Pardey et al. (1991).

Morocco (MAR)

R&D expenditure information in ASTI (2014) showed a zero value for 2003, which is not realistic. We omitted this observation.

Netherlands (NLD)

We collected information on the number of researchers of the two main public agricultural R&D entities: Dienst Landbouwkundig Onderzoek (DLO), which conducts mostly applied research, and Wageningen University (WU), which research activities can be regarded as basic research. DLO and WU together form Wageningen University and Research (WUR).

Complementary information on the number of researchers in DLO and WU was provided by the WUR administration.

New Zealand (NZL)

Hall et al. (2006) provided estimates of public agricultural R&D spending in New Zealand from 1927 to 2002. For 2003 onward, estimates of public agricultural R&D spending were taken from the annual reports of

Crown Research Institutes that conduct agricultural R&D, specifically, AgResearch, New Zealand Institute for Plant and Food Research, Scion (forestry), and Landcare Research. On January 23, 2025, the Government of New Zealand announced that these institutes would be merged into a new public research organization, Bioeconomy. To account for agricultural R&D by New Zealand universities, the Crown Research Institutes total was increased by 15 percent.

Solomon Islands (SLB)

According to Evans (2006) the main agricultural research station on Guadalcanal Island was destroyed by civil unrest in 2000 and never rebuilt. According to media reports the land was sold off and in 2025 the Ministry of Agriculture announced work had begun on building a new research station at Tenaru, also on Guadalcanal Island. There are a few substations in other parts of the country but with limited activity. We decided to impute the historical R&D spending data from Pardey et al. (1989) up to 2001 and then assumed a constant level of R&D spending onward. We assumed that the number of researchers remained constant from 2001 onward.

South Africa (ZAF)

We discarded the observation for 1981 from the ASTI (2024) number of researchers series as it showed a sharp drop. This was inconsistent with the data prepared by Liebenberg (2013) spanning the period 1910-2010, which we used to backcast the data to 1910.

South Korea (KOR)

Korean public agricultural R&D estimates for the 1980s and early 1990s prepared by Heisey et al. (2018) are approximate only as they were based on imputations. Instead, we used Choi et al. (2016), who presented statistics from the Ministry of Science and Technology for the period 1978-2000, which we combined with historical data from Pardey et al. (1991) and recent information from OECD (2024).

Tanzania (TZA)

We disregarded FAO (2024) GBARD data, which showed an implausibly steep decline between 2017-2022 in comparison to the ASTI (2024) R&D expenditure series.

United Kingdom (GBR)

We did not use number of public agricultural researchers from UNESCO (2021) for the period 2013-2017 because imputation resulted in pattern that was not consistent with the R&D expenditure series that were available for a long period.

United States (USA)

Construction of the public agricultural R&D spending series for the USA is described in Fuglie et al. (2025). Note that, in contrast to Fuglie et al. (2025), the data presented here excludes the insular territories: American Samoa (ASM), Guam (GUM), Marshall Islands (MHL), Micronesia (FMS), Northern Mariana Islands (MNP), Palau (PLW), Puerto Rico (PRI), U.S. Virgin Islands (VIR), for which separate series are

available. R&D spending of the Information for the number of researchers (1968-2021) was taken from annual reports of the Current Research Inventory System (CRIS). For the period 1993 and beyond, the number of researchers was adjusted to account for research personnel employed at United States Department of Agriculture (USDA) Economic Research Service (ERS) and U.S. Forest Service, which are not included in the CRIS reports for some years. Data for 1960-1967 was taken from Pardey et al. (1989) and spliced together with the CRIS series.

Uzbekistan (UZB)

We disregarded FAO (2024) GBARD data, which was extremely large in 2022 in comparison to the UNESCO (2021) R&D expenditure series.

Zambia (ZMB)

We disregarded FAO (2024) GBARD data, which showed an implausibly steep increase around 2017 in comparison to the ASTI (2024) R&D spending data.

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Countries with pre-1960 information

Table 1: Countries with pre-1960 information that was spliced together with the main data series. HR and RD refer to number of public agricultural researchers and public agricultural R&D expenditures, respectively.

Country	Series start year	Source	Indicator
Australia	1953	Mullen (2010)	RD
China	1953	Fan & Pardey (1992)	RD
France	1946	Lemarie et al. (2020)	RD
Japan	1897	Hayami (1975)	RD
Mexico	1947	Ardito-Barletta (1971)	RD
Netherlands	1955	Rutten (1992)	RD
New Zealand	1929	Hall & Scobie (2006)	RD
South Africa	1910	Liebenberg et al. (2013)	HR & RD
UK	1930	Thirtle et al. (2008)	RD
USA	1888	Huffman & Evenson (2006)	RD

GRAPE codes for data adjustments, data linking and imputation

Table 2: Codes for quality control adjustments and treatment of missing data.

Code	Description
none	No imputation, interpolation or data changes, excluding conversion to standard units (i.e. 2017 PPP\$ and FTE).
pa	Use of period averages for each individual year.
i_aux	Government and/or higher education series were imputed using the growth rate of an auxilliary data series (e.g. SEO-FORD or HR-RD series). EUROSTAT & OECD only.
ei	Interpolation of missing values using a constant exponential growth rate between two years.

Table 3: Codes for data linking and imputation approaches.

Code	Description
none	No linking of data.
splice_new	Data was spliced together with more recent data series applying the growth rate for overlapping years.
splice_old	Data was spliced together with older data series applying the growth rate for overlapping years.
ei	Interpolation of missing values using a constant exponential growth rate between two years.
i_naive	Imputation using naive forecasting, i.e. carry the last observation forward.
i_ens	Imputation using an ensemble of imputed values - see GRAPE documentation for details.
i_man	Manual adjustment of imputed values - see GRAPE country documentation for details.

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