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Which farms feed the world and has farmland become more concentrated?

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ABSTRACT

Numerous attempts have been made to estimate the share of the world's food produced by family farms and by farms of different sizes. This paper updates estimates of the number of farms worldwide, their distribution and that of farmland, using the most recent agricultural censuses available, in combination with survey data where needed. It finds there are more than 608 million farms in the world, more than 90% of which are family farms (by our definition), and they occupy around 70–80% of farmland and produce roughly 80% of the world's food in value terms. The paper also underscores the importance of not referring to family farms and small farms (i.e., those of less than two hectares) interchangeably: small farms account for 84% of all farms worldwide, as per the available census information, but operate only around 12% of all agricultural land, and produce roughly 35% of the world's food (well below the 80% produced by family farms). A comprehensive examination of changes in farmland distribution over time is also provided to showcase the increased concentration of farmland among large farms as economies grow. The largest 1% of farms in the world (those larger than 50 ha) operate more than 70% of the world's farmland. These estimates are not free from bias given existing data gaps. The paper underscores the need to ensure that agricultural censuses cover non-household farms in order to enhance our understanding of agriculture and food production worldwide.

1. Introduction

Numerous efforts have been made to estimate the share of the world's food produced by smallholders (FAO, 2014; Herrero et al., 2017; Ricciardi, Ramankutty, Mehrabi, Jarvis, & Chookolingo, 2018) and by family farms (FAO, 2014; Graeub et al., 2016). In some instances, the estimates made by FAO (2014) that family farms (not small farms) produce more than 80% of food in the world have been mistakenly taken as though smallholders produce more than 80% of the world's food (see, for example, Ricciardi et al., 2018). Lowder, Skoet, and Raney (2016) further provide estimates of the share of land operated by both family farms and small farms, in an effort to clarify the distinction between family farms and smallholders. These authors disseminated the complete data used for the estimates presented in FAO (2014), which were based on rounds of the FAO World Programme for the Census of Agriculture (WCA) (FAO, 2020c). Since that work was published, numerous agricultural census reports have been released through the 2010 census round of the WCA.

In this paper we extend the analysis undertaken by Lowder et al. (2016) to cover the 2010 round of the agricultural census, as well as to significantly increase the number of countries covered and to examine changes in farmland distribution over time for numerous countries. We use this newly updated dataset to examine the contributions of family farms and small farms to food production. Web Appendix A: Supplementary Information contains additional figures and tables and web Appendix B: Supplementary Data contains the updated dataset.

There are several key differences between this paper and Lowder et al. (2016) beyond the use of more updated data and broader country coverage. Where results differ, they are presented in this article and where results are largely the same (even if information is more updated), they are shown in the supplementary information available in the web Appendix A. Importantly, we provide evidence of increased concentration of farmland as economies grow. This is based on the most comprehensive analysis published to date describing average farm size and farmland distribution over time. Results suggest that agricultural land is increasingly operated

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by large scale, corporate farms. Lowder et al. (2016) provided estimates of the share of land operated by family farms and by smallholders. This paper goes one step further and provides estimates of the share of food produced by family farms worldwide as well as by smallholders from the various regions and the large developing countries, with the assumptions necessary for such estimates examined in detail.

The paper is organized as follows. Section 2 describes the data sources used and provides key definitions and concepts for the remainder of the paper. Section 3 presents the updated estimates of the number of farms and their location. Section 4 describes farm sizes and farmland distribution worldwide and by income grouping. Section 5 provides information on the share of food produced by family farms as well as by small farms. Section 6 considers changes in farmland distribution and average farm size over time. Conclusions are presented in Section 7; they include policy implications and point to necessary improvements to be made to WCA in order to maximize its usefulness to international organizations, policymakers and researchers in the Sustainable Development Goals (SDGs) era.

2. Data sources and definitions

This paper relies mostly on data from agricultural censuses to update the number of farms in the world and explore patterns around farms' size and farmland distribution. FAO has promoted WCA since 1950, by providing governments with guidance on standard methodology and contents for their agricultural census. In order to update the number of farms in the world and explore patterns, we used information from agricultural census reports from 6 different WCA rounds dating back to 1960 and including the most recent, 2010 census round. Rather than analyzing raw agricultural census data, which are generally stored at the country level and we would have preferred, we had to rely on the tabulated data as provided to FAO via agricultural census reports. By mostly using agricultural censuses, we ensure the broadest coverage of farms and farmland worldwide (see Table 1 in the web Appendix B for more details).

Agricultural holdings and agricultural area reported by the censuses generally include crop and livestock production only; holdings engaged in forestry or fisheries are only included if they are also engaged in crop and livestock production. Communal lands are generally not included in the agricultural census. The exclusion of forests and communal lands means that the farm sizes are smaller than they would be were forests and communal lands included.

FAO's definition of an agricultural holding is: "an economic unit of agricultural production under single management comprising all livestock kept and all land used fully or partly for agricultural production purposes, without regard to title, legal form, or size. Single management may be exercised by an individual or household, jointly by two or more individuals or households, by a clan or tribe, or by a juridical person such as a corporation, cooperative or government agency" (FAO, 2005).

This article uses the terms agricultural holding and farm interchangeably – mostly making use of the latter. The agricultural holder or farmer makes strategic decisions regarding the use of the farm resources and bears all risks associated with the farm. The agricultural holder may serve as manager or delegate daily management responsibilities to a hired manager (FAO, 2005).

As with any source of information, agricultural census reports and the censuses themselves present limitations. By relying on agricultural census reports rather than raw agricultural census data – which are not available for the large number of countries analyzed here, we are limited to considering only the information that is presented in the agricultural census reports and we may only consider it as it has been tabulated by the authors of the report. Furthermore, the censuses themselves present limitations. For instance, FAO recommends that censuses should consider farms of all types throughout a country and be conducted by using complete enumeration and/or sampling methods. Despite this recommendation, some agricultural censuses survey farms that are associated with a household (household farms) rather than all farms, thus excluding corporate entities and government holdings which can potentially lead to important underestimation for some countries. This is true, for instance, in the 2010 census round for many African countries, including Ethiopia, Malawi and Rwanda (Lowder et al., 2016). To the extent that this is the case, our estimates of average farm size are biased downward. Evidence for Tanzania, Zambia, Cambodia and Mongolia is indicative of the magnitude of the problem.

Tanzania's Agricultural Census for 2008 give us an idea of the contribution of non-household and household farms to overall production. The 2007/08 census found 1006 large farms (non-household farms) and 5.8 million smallholders (household farms) in Tanzania (Government of Tanzania 2012b, 2012a). Seven percent of farm area in the country was found on the large farms while only 93% was found on smallholders' farms. Large farms harvested about 7% of cereals in the country; they were especially invested in wheat and responsible for harvesting nearly 80% of wheat in 2007/08. Large farms were also responsible for large shares of cash crops in the country; they harvested 63% of tea, 34% of tobacco and 15% of coffee. A survey that is limited to agricultural households only would clearly not gain a complete picture of agriculture in Tanzania.

In 2001/2002 Zambia carried out its annual survey of large-scale farms (defined as household or institutional farms farming more than 20 ha of crops or with more than a certain number of

Table 1
Share of harvested or cultivated cropland area and share of value of crops produced, by farm size in Brazil, Colombia, Cambodia and the United States of America

	Brazil, 2006		Colombia, 2013		Cambodia, 2011		United States of America, 2012	
	Share of harvested area	Share of value produced	Share of harvested area	Share of value produced	Share of cultivated area	Share of value produced	Share of harvested area	Share of value produced
< 5 ha	12%	9%	20%	20%	36%	37%	0%	0%
5–10 ha	7%	6%	16%	15%	19%	18%	0%	0%
10–20 ha	11%	10%	17%	16%	17%	18%	0%	0%
20–50 ha	17%	16%	19%	18%	16%	14%	2%	2%
50–100 ha	11%	11%	10%	10%	5%	4%	4%	4%
100–200 ha	11%	12%	7%	8%	5%	3%	8%	9%
200–500 ha	17%	19%	7%	8%	3%	6%	22%	24%
> 500 ha	15%	18%	5%	5%			64%	60%

Source: Calculated using agricultural census data compiled by Ricciardi et al. (2018) on harvested area and production quantity by farm size, crop and geographic area. Production quantities by crop are a weighted sum using data on average producer price for the years 2009 to 2011 from FAO (2020a). Producer prices are specific to the crop, country and year.

livestock). It found that large farms were responsible for 30% of food production in the country (Government of Zambia, 2004).

Cambodia conducted its first ever agricultural census in 2013 (Kingdom of Cambodia, 2015). That census included 101 non-household farms (referred to as juridical holdings) in addition to nearly 1.9 million household farms. Juridical holdings are managed and operated by government or private enterprises; the census showed that juridical holdings operate 20% of agricultural land in the country. Clearly the inclusion of non-household farms is important for gaining a comprehensive picture of agriculture in Cambodia as well.

Covering non-household farms is important to gain an understanding of food production in Mongolia. An agricultural census for Mongolia covered non-household farms in addition to agricultural households; it refers to the former as business units and organizations (BuO) (Government of Mongolia, 2012). The production statistics that result show that BuO are responsible for only a small share of meat and milk from livestock. The BuO are however responsible for 90% of wheat production, 29% of potato production and 16% of vegetable production.

A few African countries have not conducted an agricultural census since the 1980 round or earlier. In these cases, we also used data from Living Standards Measurement Study (LSMS) surveys and Demographic and Health Surveys (DHS) in order to have a more recent estimate of the number of farms. The limitation in this case is that this estimate includes only household-owned and operated farms, but not corporate farms, which are typically much larger than household operated farms. As a result, our estimates of average farm size are biased downward.

LSMS surveys are the result of a decades-long collaboration between the World Bank and National Governments. A comprehensive description of LSMS data and survey design is beyond the scope of this paper. For more detailed information about LSMS surveys readers are referred to (World Bank, 2020b). For Nigeria, LSMS estimates of agricultural households are used as a proxy for the number of agricultural holdings or farms in those countries and we also used LSMS data to estimate agricultural land distribution among households. The land variable is a self-reported estimate of agricultural land cultivated for crops or livestock use. Agricultural land is land cultivated and owned, excluding land rented out but including land rented or sharecropped in. Fallow land is included. For Kenya a household survey is likewise used.

For Burundi, Ghana and Zimbabwe, we use the DHS administered by the United States Agency for International Development (USAID) and its partner organizations, in order to obtain the number of agricultural households as a proxy to estimate the number of farms in those countries. Since 1984, USAID has implemented the DHS which are nationally representative household surveys on various health-related concerns in over 70 developing countries throughout the world (USAID, 2006). In the mid-2000s, questions on ownership of agricultural land were introduced in some of these surveys to understand if any member of the household owned agricultural land and how many hectares. In this case, agricultural land refers to what the DHS interviewer's manual stipulates: "Agricultural land refers to land that is used for growing crops (the crops may be food for people, food for animals, or other non-food crops), raising animals, and grazing animals. In answering this question, common land used to graze animals but not owned by the household should not be included" (USAID, 2012). Moreover, the DHS data are useful for compiling the share of the population involved in agriculture as well as average household size or the number of household members. By combining this information with population statistics from FAOSTAT, we created rough expansion factors that allowed us to estimate the number of households that own agricultural land as well as the total agricultural land in those three countries.

3. Number of farms and their location

Nagayets (2005) used agricultural census data from FAO to estimate that there are about 525 million farms of all sizes in the world. Hazell, Poulton, Wiggins, and Dorward (2010) used similar data to arrive at about 500 million small farms (those with less than two hectares) worldwide. The latest estimate by FAO (2014), later published by World Development (Lowder et al., 2016), points to more than 570 million farms worldwide. Here we present an updated estimate that is based on methodology comparable to that used for the estimate presented in FAO (2014).

We estimate that the total number of farms in the world is now more than 608 million (see Table 1 in the web Appendix B). This is larger than the previous estimate of greater than 570 million, which is partly due to our increased country coverage (179 countries instead of 167). For numerous reasons, however, we expect that the number of farms in the world is larger than 608 million. We report estimates of the number of farms in 179 countries and territories; however, an agricultural census that reports the number of farms is lacking for about 30 countries or territories. Including estimates from those countries would, of course, have increased the total estimated. Secondly, many of the estimates of number of farms for low- and middle-income countries are from outdated agricultural census rounds. For a number of countries (Angola, Cameroon, Chad, the Dominican Republic, Gabon, Iraq, Liberia and Singapore) the most recent census was conducted with the 1970 round. Thirdly, as further explained below, average farm size has decreased while the number of farms worldwide has increased from 1961 to 2010, largely as the number of farms rose in low- and middle-income countries, which represent the vast majority of farms worldwide. Lastly, as noted, for many countries in Africa and Asia, the estimated number of holdings is limited to the number of household farms, with non-household farms not included in the sample frame; again, this means that our estimate is biased downward. For these reasons we may conclude that there are now more than 608 million farms worldwide.

Farm sizes and the total number of farms change over time as a result of population growth, agricultural development, land policies and other socio-economic and climatic factors. We might expect that in some countries the number of farms in past decades has little bearing on the current number of farms in those countries. Regardless, this is the most complete estimate available today, and the vast majority of farms were reported from more recent agricultural census rounds (1990, 2000 or 2010). These estimates will not change rapidly given agricultural censuses are conducted every 10 years and it will thus take time for results to emerge for many countries.

The location of such farms according to region as well as classification by income level differs little from that presented in Lowder et al. (2016). As such, it is shown in Figure 1 of the web Appendix A.

4. Distribution of farms and farmland area by land size class

Estimating the frequency of farms by farm size class give us an idea of the average size of farms operated by most farmers, while the share of agricultural land by farm size class is an indication of the size of farms upon which the majority of farmland is found. Prior to this updating, the most recent and comprehensive estimate of these indicators was published by Lowder et al. (2016) in *World Development*. They drew from the methodology described in FAO (2014) and our updated estimate is comparable to theirs.

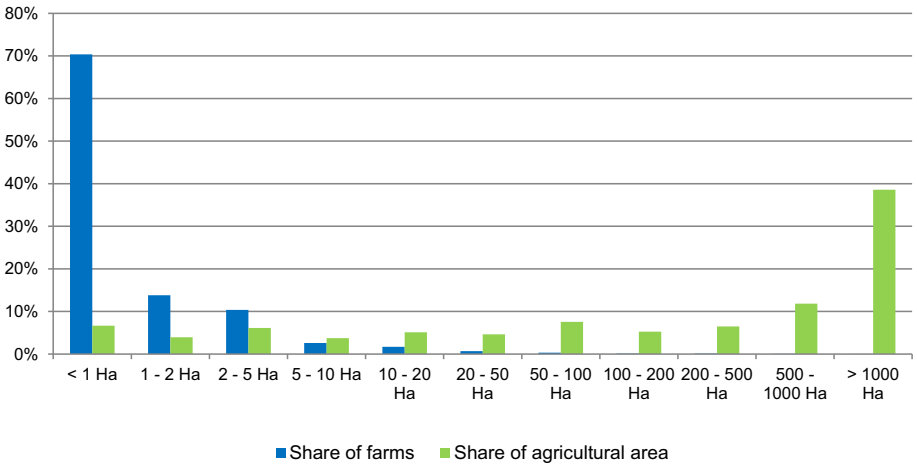

Fig. 1. Worldwide distribution of farms and farmland, by land size class. (Notes: estimates for 129 countries and territories in the world. For details see Tables 2 and 3 in the web Appendix B). Sources: authors' compilation using FAO (2001), FAO (2013) and agricultural census reports from the 2010 census round (see "Sources: Agricultural census reports and information consulted" in the web Appendix B).

4.1. Distribution worldwide

Here we present the most comprehensive estimate possible of the distribution of farms and farmland by land size class. We have data on the number of farms by land size class for 129 countries and territories. For all but 19 of these, we also have information on total agricultural area and agricultural area by land size class. For the 19 countries with missing information, FAOSTAT estimates of arable land and permanent crops were used to fill the gap on agricultural area. For those countries, we estimated agricultural area by land size class cohort by computing the product of the midpoint of that land size class cohort (i.e., 0.5 ha for the zero to one hectare cohort) and the number of farms in that cohort – ensuring that the resulting total agricultural area did not exceed total agricultural area in the country. In some cases, the total agricultural area resulting from such estimates exceeded the total agricultural area in the country. To eliminate such discrepancy, we uniformly reduced the amount of agricultural land in each land size class cohort until the amount in the largest cohort divided by the number of farms in that cohort was roughly equal to the midpoint of the largest cohort.

The results show that, worldwide, farms of less than one hectare, account for 70% of all farms, but operate only 7% of all agricultural land (Figure 1). Slightly larger farms between one and two hectares, account for 14% of all farms and control 4% of the land. Together, farms of less than two hectares total about 510 million; they account for 84% of all farms, but operate only around 12% of all agricultural land. Farms in the range of two to five hectares account for 10% of all farms and control 6% of the land. Interestingly, the largest 1% of farms in the world (those larger than 50 ha) operate more than 70% of the world's farmland. Here we see an even more unequal distribution of land than reported by Lowder et al. (2016); they estimated that the share of land in the >1000 ha category was nearly 20% using a sample of 106 countries, whereas our estimate using a sample of 129 countries (and more recent estimates for many of those countries) is that nearly 40% of land is found on farms larger than 1000 ha. While this high concentration of land among very large farms is to a large extent due to the inclusion of Australia in the updated dataset, it may also reflect an increased concentration of farmland area over time, as will be further explained below in Section 6.

Much work by international organizations focuses on increasing the productivity of smallholders, often defined as those agricultural holders operating areas smaller than two hectares. Indeed, to improve rural livelihoods, it is important to improve the productivity of smallholders – or to increase their income earning, whether on-farm or off-farm. However, to the extent that international organizations focus on what is happening at the lower end of the distribution, their attention may be diverted away from the state of medium and large scale farms which represent the vast majority of agricultural land. It would be difficult, if not impossible, to have an unbiased picture of the state of large scale and corporate agriculture if international organizations focus only on smallholders and small farms. This would hide important information on all types of farms, which will also be critical to achieve a number of Sustainable Development Goals (SDGs), and certainly those of eradicating poverty (SDG 1), achieving Zero Hunger (SDG 2), addressing inequalities (SDG 10) and achieving more sustainable production patterns (SDG 12).

4.2. Distribution by income level

To draw the big picture, we look at farmland distribution based on the income level of 123 countries (Figure 2). For nearly all income levels, on average, a large share of farms (between 40 and 85%) are smaller than two hectares; they control anywhere from a few% to nearly 40% of farmland. The farmland share represented by the larger cohorts would seem to increase with each income category. For example, farms greater than five hectares in size cover 28% of the farmland in low-income countries, nearly 40% in the lower-middle-income countries, 85% in the upper-middle-income countries and nearly 99% in the high-income countries. In short, it would appear that the share of farmland controlled by larger farms is higher in countries with larger average incomes.

We also see that smaller farms operate a far greater share of farmland in lower-income countries and regions than in higher-income countries and regions. In the low- and lower-middle-income countries (which are located primarily in East Asia and the Pacific, South Asia and sub-Saharan Africa), about 80% of farms on average are smaller than two hectares, similar to the global average, and they operate about 30 to 40% of land, a much larger share of land than in other regions. In upper-middle-income countries nearly 90% of farms are smaller than two hectares and they operate 10% of land; the large share of farms in the small farm category largely reflects the situation in China rather than the other countries in that grouping. In high-income countries, only about 50% of farms are smaller than two hectares in size, and they operate less than 5% of farmland. This pattern suggests that the share of

Fig. 2. Average distribution of farms and farmland area by land size class and income group. (Notes: number of countries are indicated in parentheses. Country income and regional groupings for this figure and throughout the article and web Appendices are the same as those used for fiscal year 2011 by the World Bank (World Bank, 2020a). For country level data see Tables 2 and 3 in the web Appendix B). Sources: authors' compilation using FAO (2001), FAO (2013) and agricultural census reports from the 2010 census round (see "Sources: Agricultural census reports and information consulted" in the web Appendix B).

farmland managed by small farms decreases as average income levels rise and indicates that farmland becomes more concentrated among larger farms as economies develop. Section 6 will examine changes in farmland distribution over time for those countries for which such information is available.

The distribution of farms in low- and middle-income countries by region differs little from the results shown in Lowder et al. (2016). It is shown in Figure 2 of the web Appendix A.

5. Share of food produced by family farms and small farms

Family farms are an important part of the farms we have accounted for above. They figure prominently in the discourse about agricultural development, and the international community has paid more attention to them both through the SDGs and the UN Decade of Family Farming. However, definitions of family farms are still often unclear. This section intends to shed light on these con-

cepts and having done that, it provides estimates of farms in their different dimensions.

While definitions of what a farm is are well established (see, e.g. FAO, 2015), there is no universally agreed definition of family farms, given the enormous diversity of this group and depending on the country context. Indeed, every country may have its own definition for family farms. Nonetheless, various stakeholders have established definitions either for purely analytical purposes or for the implementation of government programs. The *United Nations Decade of Family Farming 2019–2028 – Global Action Plan*, developed by FAO and the International Fund for Agricultural Development (IFAD), applies the notion of "family farming" referring to all types of family-based production models in agriculture, fisheries, forestry, livestock and aquaculture, and includes peasants, indigenous peoples, traditional communities, fisher folks, mountain farmers, forest users and pastoralists (FAO & IFAD, 2019).

We use evidence from the 2010 census round of agricultural censuses to update estimates made by FAO (2014), which were subsequently reported in Lowder et al. (2016), of the number of family farms as well as the share of agricultural land they operate, with the resulting implications for their contribution to total food and agricultural production. The need to take stock of the number of family farms at global level by means of a cross country analysis calls for a single definition.

We define family farms as those farms held by an individual, group of individuals or household whose labor is mostly supplied by the family. This conforms to the definition used by FAO (2014) and Lowder et al. (2016) and is based on a review by Garner & de la O Campos (2014) of common characteristics of family farms as found in their review of 36 definitions of the term "family farm". Following a convention used by many researchers (see, for example, Hazell et al., 2010; HLPE, 2013; Wiggins, Kirsten, & Llambí, 2010), we define small farms as those agricultural holdings that encompass fewer than two hectares of farmland.

Other researchers have tried to answer the question of how much of the world's food is produced by family farms or by smallholder farms. FAO (2014) showed that family farms (not small farms) produce more than 80% of food in the world. The complete data used for the FAO (2014) estimates were made publicly available by Lowder et al. (2016), but these authors did not present estimates of the share of food produced by family farms or small farms. Graeub et al. (2016) provide an estimate that 53% of the world's food is produced by family farms, when these are defined on a country-specific basis including with regard to size. Herrero et al. (2017) combined farmland distribution data from Lowder et al. (2016) with crowd sourcing and satellite imagery to show that farms smaller than two hectares produce about 30% of most food commodities in sub-Saharan Africa, Southeast Asia and South Asia. At the global level, between 10 and 35% of food from categories including vegetables, sugar crops, roots and tubers, pulses, oil crops, livestock, fruit, fiber and cereals are produced by farms smaller than two hectares. Ricciardi et al. (2018) use crop specific data and data on farm size for 55 countries combined with FAOSTAT data to show that farms smaller than two hectares are responsible for 30–34% of food supply in those countries.

Comprehensive analysis of the relationship between farm size and output is not available. Nevertheless, Sheng and Chancellor (2019) and MacDonald et al. (2017) find an uneven distribution of farm output by farm size in Australia and the United States, respectively. In terms of total output, small farms account for only 30%, while the remaining 70% is produced by medium and large farms, mainly because of differences in the distribution of production inputs.

Here we estimate the share of food produced by family farms and by smallholders using the approach taken in FAO (2014). In order to approximate the share of food produced by family farms and by smallholders, we use the share of land they operate as a rough proxy for their share of the value of food production. Because there are no international datasets showing food or agricultural production by farm size or farm type for numerous countries (Ricciardi et al., 2018), we rely on the assumption that food and agricultural production is proportional to agricultural area; another way of saying this is that yields are constant regardless of farm size. This is an assumption used by others including FAO (2014) and Graeub et al. (2016) in view of the lack of data. Before continuing, let us first examine the assumption using a review of the literature and limited data that are available.

Empirical evidence on the farm size–productivity relationship is not only ambiguous, but it also differs among countries. A group of studies showing that the larger the farm, the stronger the positive relationship between size and productivity (Deininger & Byerlee, 2012; Deininger, Nizalov, & Singh, 2013; MacDonald, Hoppe, & Newton, 2017; Sheng & Chancellor, 2019). This strong and positive relationship is also observed between size and productivity growth (Key, 2019; Knopke, O'Donnell, & Shepherd, 2000). In both cases, the positive relationship is linked to technological changes and farmers' capital choice, and the evidence mostly comes from continental countries such as Australia and the United States, some Latin American countries and Ukraine.

Another group of studies provides evidence of an inverse farm–size productivity relationship in developing Asian, Latin American and Sub-Saharan African countries (Barret, Bellemare, & Hou, 2010; Carletto, Savastano, & Zezza, 2013; Desiere & Jolliffe, 2018; Heltberg, 1998; Kagin, Taylor, & Yúnez-Naude, 2015). There are several explanations supporting this traditional inverse relationship hypothesis in the literature, which can be organized in three different groups of studies. The first group focuses on imperfect factor markets, more specifically on imperfect competition and distortions in land and labor markets between large and small farms (Ali & Deininger, 2015; Deininger et al., 2018; Kagin, Taylor, & Yúnez-Naude, 2015). Similarly, technology adoption and input choice between labor and capital strongly differs among farms of different sizes (Henderson, 2014; Liu, Violette, & Barrett, 2013; Otsuka, Liu, & Yamauchi 2016). Finally, this group of studies focuses more on unobserved factors (i.e. soil quality and climate conditions) that could be unevenly distributed between large, medium, and small farms (Assunção & Braido, 2007; Barret, Bellemare, & Hou, 2010; Foster & Rosenzweig, 2017).

A third group of recent studies have found that the inverse farm size-productivity relationship can be attributed to systematic measurement errors, specifically those associated with respondent-reported plot sizes and self-reported production (Carletto, Savastano, & Zezza, 2013; Desiere & Jolliffe, 2018; Dillon et al., 2019; Holder & Fisher, 2013).

There is a fourth line in the literature that discuss the farm size–productivity relationship as a U-shaped relationship, mainly in developing countries. Foster and Rosenzweig (2017) find that both large and small farms in India are more productive than medium-size ones due to fixed transaction costs in the form of wages paid to workers. They also show that the rising upper tail of the U is because of economies of scale in the use of machinery, which is a characteristic of high-income countries. Muyanga and Jayne (2019) find similar results in Kenya. Other evidence suggests that when agricultural intensification is accounted for, no relationship is seen between plot size and productivity (Wassie, Abate, & Bernard, 2019).

Agricultural census reports often record the number of farms by farm size class and a measure of the area of the farm which is most often operated area or agricultural area. Unfortunately, information on production by farm size is only available for very few coun-

tries. The database used for analysis in Ricciardi et al. (2018) compiles information from agricultural censuses and household surveys. For many agricultural censuses information is not available on both production by farm size and agricultural area by farm size. Where such information is missing, the authors approximate production by farm size using agricultural area by farm size combined with national yield indicators from FAOSTAT. This implies that yields are constant across farm sizes, an assumption that is similar to the one made by Graeub et al. (2016) and FAO (2014) that food production is proportional to agricultural area.

Despite the limitations of data on agricultural production and farmland, there are some countries in the Ricciardi et al. (2018) database, with data from agricultural censuses that include both production estimates and measurements of harvested area by farm size. There are no African or European countries with that information in that dataset. Results in Table 1 suggest that the share of the value of crop production in Brazil, Colombia, Cambodia and the United States of America is proportional to the share of area harvested to those crops.

Table 1 above presents estimates of area harvested and agricultural production, but the data we use for this article are largely describing total agricultural area. We therefore examined the association between agricultural area and net food production, using data from FAOSTAT for the years 2009 to 2011. As shown in Figure 3 below, there is a strong correlation between agricultural area and food production.

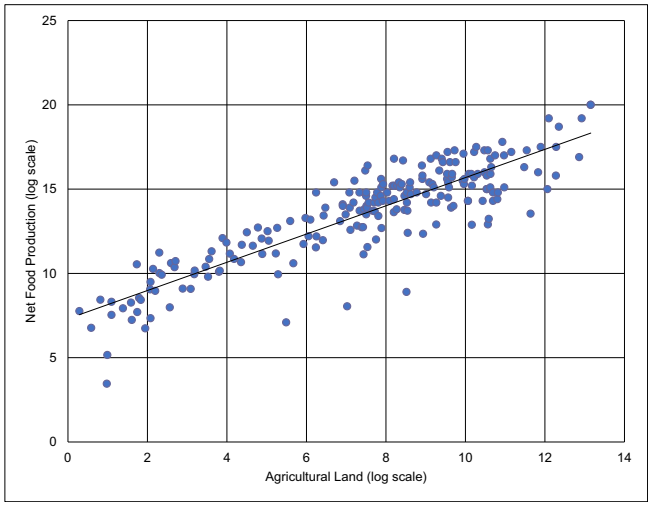

Fig. 3. Agricultural area and net food production. (Notes: the scatterplot shows data for 216 countries and territories. For both indicators we use the average for 2009 to 2011. The value of net food production is measured in thousands of constant international dollars at base year 2004–2006). Source: Authors' calculations using data from FAO (2020a).

Armed with the above evidence on the plausibility of proportionality between agricultural land and food production, we proceed to estimate our rough approximation of the share of food produced by family farms. We replicate the method used by Lowder et al. (2016) to estimate the number of family farms in the world as well as the share of land they operate. Briefly stated, family farms are those farms operated by an individual or group of individuals and where most labor is supplied by the family. Our results show that there are more than 550 million family farms worldwide; which is 50 million more than previously estimated in FAO (2014) and Lowder et al. (2016) and 78% of land is operated by these 550 family farms. Details are presented in web Appendix A.

Using the value of food production in 2015 at the country level and multiplying this by the share of land operated by family farms, we find that the weighted average across countries is 77% (out of a sample of 53 countries). Based on this, we conclude that family farms produce roughly 80% of the world's food in value terms (Figure 4). This would imply that family farms, as defined here, are likely to be responsible for the majority of the world's agricultural and food production. However, family farms, as defined in this paper, are a diverse group which includes farms of all sizes. In designing policies for agricultural development, it is then necessary to distinguish among different types of family farms.

We also saw that worldwide, farms of less than two hectares account for approximately 84% of all farms and operate about 12% of all agricultural land (Figure 1). To make a rough estimate of the share of food produced by farms smaller than two hectares, or small farms, for each country (out of a sample of 112 countries), we multiplied the share of land operated by these farms by the value of food production in 2015. We then looked at the sum across countries to obtain the worldwide average (weighted by the value of food production), which points to roughly 35% of the world's food being produced by small farms (Figure 4). We also see that the share of food produced by small farms varies widely across and within income and regional groupings (Figure 5): it is larger in developing regions than in high-income countries and, within the former, it is the largest in East Asia and the Pacific, South Asia and sub-Saharan Africa (excluding Nigeria).

These estimates of roughly 80% and 35% of the world's food being produced by family and small farms, respectively, rely on

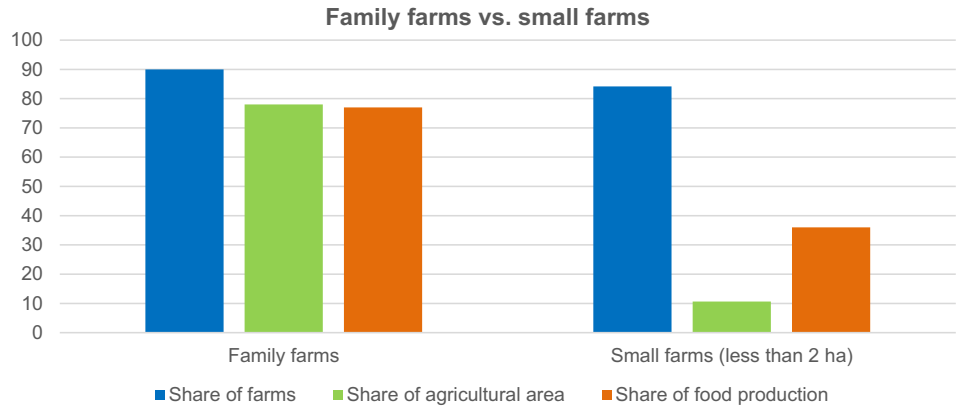

Fig. 4. Family farms and small farms – share of holdings, share of agricultural area and share of food production. Sources: authors' compilation using FAO (2001), FAO (2013) and agricultural census reports from the 2010 census round (see "Sources: Agricultural census reports and information consulted" in the web Appendix B). Value of food production is from FAO (2020a).

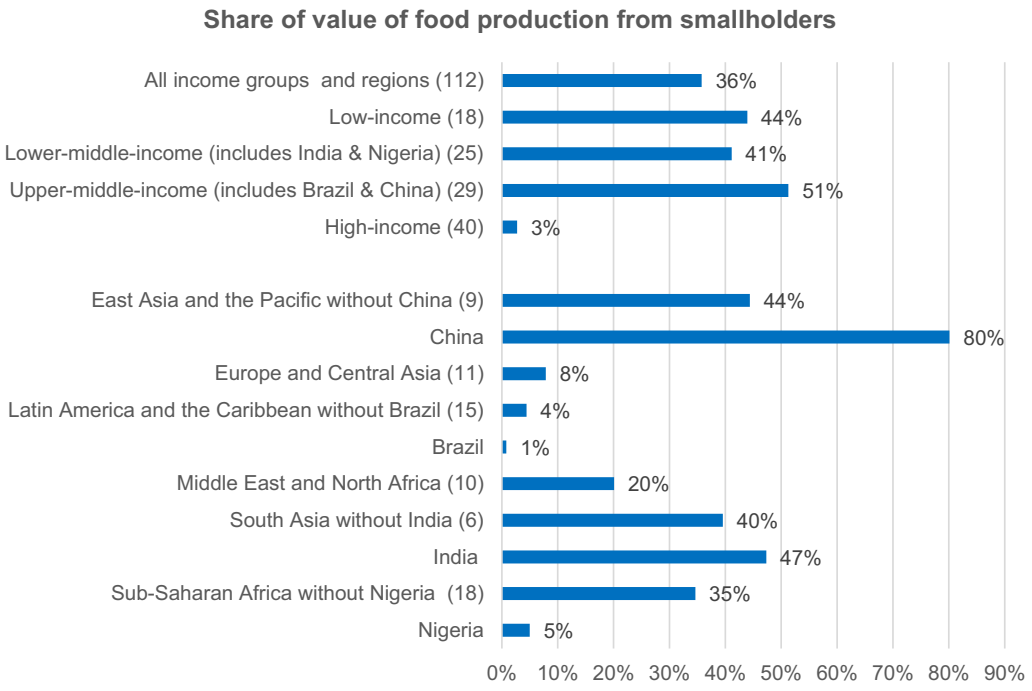

Fig. 5. Share of value of food production from smallholders, by region and income grouping. (Note: number of countries in parentheses). Sources: authors' compilation using FAO (2001), FAO (2013) and agricultural census reports from the 2010 census round (see "Sources: Agricultural census reports and information consulted" in the web Appendix B). Value of food production is from FAO (2020a).

the simplifying assumption that the share of land farmed by a type of farmer in a country determines the share of the food produced by that farmer type. Regardless of the actual share of food produced by smallholders and that produced by family farms, we can be relatively confident that smallholders are responsible for a small share of the world's food production and family farms are responsible for much of the world's food production. This is due to the fact that the majority of land is operated by family farms of all sizes and a minority of agricultural land is operated by small farms.

This stark contrast makes clear the importance of how we are defining terms and distinguishing among the different types of farms when engaging in policy discourse. The policies needed for the largest farms in the world are most certainly different from those needed for resource poor and land scarce farms in the developing world. It is imperative that we avoid the use of the terms family farms and small farms interchangeably. It would be helpful to distinguish among family farms by farm size.

6. Farmland distribution and farm size over time: is farmland becoming increasingly concentrated among large farms?

By considering farmland distribution, we learn about the welfare of farmers as well as gain indications of the extent of agricultural transformation. In a country where a large share of gross domestic product (GDP) comes from agriculture (as opposed to industry or services), and where a large number of very small farms are in operation, we might imagine that there is a large share of the population engaged in subsistence agriculture. In such an agricultural economy, an increase in the number of small farms over time may raise concerns regarding the well-being of smallholder farmers and the degree of agricultural transformation. An increase in the share of land farmed on large farms might raise concerns that agricultural development is not favoring small-scale farming and has an important environmental footprint. Numerous factors underlie changes in farmland distribution and they are beyond the scope of this article. These include, for example, land tenure policy, population density and population growth, the availability of arable land and off farm employment opportunities, among others (see, for example, Tan, Robinson, Li, & Xin, 2013; Jayne, Chamberlin, & Headey, 2014; Sitko & Jayne, 2014; Dawe, 2015; Van Vliet et al., 2015). Changes in methodology and definitions used from one agricultural census to the next also affect the trends observed over time. However, our analysis of farmland distribution and farm size over time, based on the census data, sheds lights on possible transformations of agriculture in the world.

6.1. Insights from the literature

Much literature on changes in average farm size as well as farmland distribution over time can be summarized as finding that average farm sizes have increased in the developed world and decreased in the developing world (see, for example, Dawe, 2015; Eastwood, Lipton, & Newell, 2010; Union, 2015; FAO, 2013; Hazell et al., 2010; HLPE, 2013; Van Vliet et al., 2015). Exceptions to this include the finding in Jayne et al. (2014) that average farm sizes have increased in recent years in some land abundant countries in Africa, while decreasing in land constrained contexts. Masters et al. (2013) point to recent increases in average farm sizes for parts of Asia. Lowder et al. (2016) found that average farm size increased from 1960 to 2000 in some upper-middle-income countries.

Jayne et al. (2016) find an increase in recent years in the number of medium-sized farms (5–100 ha) as well as in the share of land they operate in Ghana, the United Republic of Tanzania and Zambia, but not in Kenya. Increases in the number of medium-scale farms in Zambia are attributed to salaried urbanites and relatively well-off rural inhabitants, rather than to increased farm size by smallholders who began farming areas smaller than five hectares. The change is attributed to land administration and agricultural spending policies (Sitko & Jayne, 2014). The literature

reviewed also confirms an increase in average farm size in China (from 1996 to 2006) (Tan et al., 2013). Our literature review found no work that considers evidence worldwide from the 2010 census round of agricultural censuses. In this article, we extend the analysis of farmland distribution and average farm size undertaken by Lowder et al. (2016). We consider changes in farmland distribution and average farm size over time for select countries and examine changes in average farm size updated to include the 2010 round of the agricultural census as well as increase the number of countries.

6.2. Change in farmland distribution over time for selected countries

Available data allow us to look at farmland distribution over time for a select number of countries. First, we see the case of Brazil and the United States of America, two countries that are among five that represent the largest share of the world's agricultural area – 5% and 8%, respectively, in 2010 (FAO, 2020a). Both countries may also be characterized as having a large share of their agricultural area being found on large farms (Figure 6). In Brazil, the share of holdings that are small (less than two hectares) has increased from 1970 to 2017. At the same time, the share of agricultural area farmed by the 2% of farms that are larger than 500 ha went up to about 58% in 2017, from 51% in 1970. In the United States of America, on the other hand, there has likewise been an increase in the share of farms that are smaller than five hectares, as well as those smaller than 20 ha. The share of area farmed by farms in the largest category (greater than 500 ha) has also increased.

For both of these countries to exhibit an increase in the share of farms that are of the smallest size and an increase in the share of farmland farmed on the largest holdings has implications for equity and the food system. In addition to suggesting increased

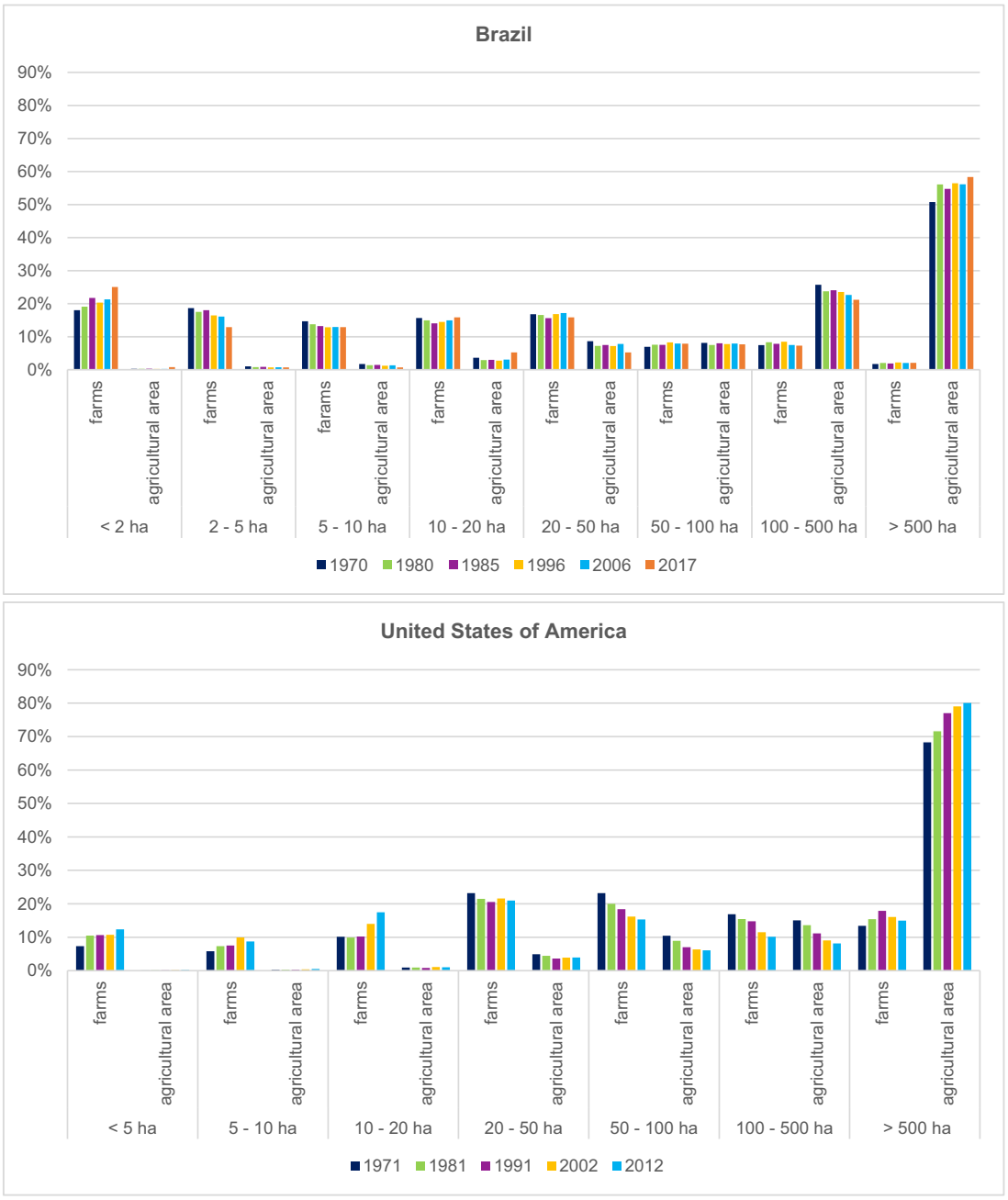

Fig. 6. Farmland distribution over time in Brazil and the United States of America from the 1970s. Sources: FAO, 2013; IBGE, 2009, 2018; USDA, 2014.

inequality, there may be a rise in small-scale farms producing food that is consumed close to the source as well as an increasingly important role being played by large scale corporate farming. The issue of the emergence of small farms in countries such as Brazil and the United States of America, among other possible countries, goes beyond the scope of this paper, but it deserves more study.

We also look at the change in farmland distribution from 2005 to 2013 in the European countries with the largest agricultural area. None of these countries show an increase in the share of farms that are smaller than two hectares. However, for France, Germany and the United Kingdom of Great Britain and Northern Ireland, we see that the share of agricultural area operated by farms larger than 100 ha has increased (Figure 7) – which is one pattern shown in the cases of Brazil and United States of America. Spain has not exhibited such an increase. Future work might also consider looking at the evolution in farmland distribution in those countries prior to 2005.

Looking at countries of lower development, Figure 8 shows the evolution of farmland distribution in Ethiopia, India and the Philippines from the 1970s until more recent times. Unlike the other countries described above, whose per capita incomes are by and large relatively higher, the share of farmland operated by larger farms has decidedly decreased over the period in both India and the Philippines. In Ethiopia, a similar decrease in the share of farmland operated by larger farms was observed until the year 2000, after which time the trend seems to have reversed and an increasing share of farmland in that country has been operated by farms larger than two hectares.

6.3. Trends in average farm size

For another indication of what trends are evident in the evolution of average farm size, we examine the evolution of weighted average farm size at the regional and income group level, using interpolations – as described in Table 1 of the web Appendix A. To calculate the weighted average farm size by income or regional group, we used the number of agricultural holdings reported in the corresponding agricultural census. Where number of holdings was not available, interpolations and extrapolations were likewise used.

We caution that our sample is not globally representative, but it does allow us to consider representative trends for high-income countries, and most regions, except East Asia and the Pacific (estimates are not available for China) and Europe and Central Asia (estimates are not available for the Russian Federation). We are able to examine trends for 129 countries here, which is an increase from the sample of 72 countries considered by Lowder et al. (2016).

We find that average farm size is largest for high-income countries other than Europe, followed by Latin America and the Caribbean, Europe and Central Asia, and high-income European countries. Average farm size increased for the high-income countries in Europe from about 12 ha in the 1960s to 21 ha in the 2010 census round. It also increased from 33 ha in 1960 to 41.5 ha in the 2010 census round in Europe and Central Asia. It decreased in Latin America and the Caribbean from about 70 ha per farm in 1960 to about 40 ha in the 2010 census round. The average for high-income countries outside of Europe increased from 86 ha in 1960 to 115 ha in 1990, before decreasing to 78 ha in the 2010 census round (Table 2).

Average farm size is smallest in South Asia, followed by East Asia and the Pacific, sub-Saharan Africa and the Middle East and North Africa. Average farm size has decreased over the period for East Asia and the Pacific. The trend in South Asia is a clear decrease in average farm size from about 2.6 ha per farm in 1960 to 1.2 ha in 2000, followed by a slight increase to 1.4 ha, which largely reflects the situation in India. The average size of farms in countries of the Middle East and North Africa decreased from 1960 to 2000, before increasing slightly in the 2010 census round. A similar pattern is seen for sub-Saharan Africa where the decrease in average farm size is evident from 1960 to 1990, after which point average farm size has slightly increased.

Considering average farm size by income group we also see that, over much of the period, the average farm size is largest in high-income countries, followed by upper-middle-income, then lower-middle-income and lastly low-income countries (Table 3). This is suggestive of increased concentration of farmland as economies grow, an observation that is consistent with theories of structural transformation. For low- and middle-income countries, average farm size has steadily decreased from 1970 to 2010, with the exception of the most recent period (2000 to 2010) over which time the average for low-income and lower-middle-income countries increased slightly. Examining the country level estimates (see Table 5 in the web Appendix A), we see that from 2000 to 2010, average farm size indeed increased in some of the low-income countries for which we had information; these include Bangladesh, Ethiopia, Malawi, Mozambique, Togo and United Republic of Tanzania.

7. Conclusion, policy implications and recommendations

After a thorough analysis of agricultural census reports, and keeping in mind important data limitations and how these bias our estimates, our review of the number of farms and family farms worldwide, as well as trends in farmland distribution and average farms size, leaves us with a number of interesting updates and findings. There are more than 608 million farms in the world and greater than 90% of them (more than 550 million) can be considered family farms as they are run by an individual or a family and rely primarily on family labor. Estimates suggest that family farms occupy around 70–80% of farmland and produce roughly 80% of the world's food in value terms. These family farms must not be confused with small farms (those smaller than two hectares), which, according to our estimates, account for 84% of all farms worldwide, but operate only around 12% of all agricultural land and produce about 35% of the world's food. Such estimates of the share of food produced by family farms and that produced by small farms must be considered rough approximations based on generous assumptions. More accurate estimates would be possible if we were to have country level data on both production and a measure of agricultural land by farm type and commodity.

We find evidence of increased concentration of farmland among large farms as economies grow. First, for most of the period 1960–2010, average farm size was largest in high-income countries, followed by upper-middle-income, then lower-middle-income and lastly low-income countries. Second, the share of farmland controlled by larger farms tends to be higher in countries with larger average incomes. Indeed, we find evidence that farmland is more unequally distributed in favor of the larger farms in regions of higher per capita income such as Latin America and the Caribbean, but also Middle East and North Africa, compared to other regions of low- and middle-income countries. Thirdly, we also see that smaller farms operate a far greater share of farmland in lower-income regions than in higher-income countries, suggesting the share of farmland managed by small farms diminishes as average income levels rise. Fourthly, low-income countries have, on average, shown a slight increase in average farm size (from 2000 to 2010). Last, the share of farmland farmed on the largest holdings has increased in Brazil, in several European countries (France, Germany and the United Kingdom of Great Britain and Northern Ireland) and in the United States of America.

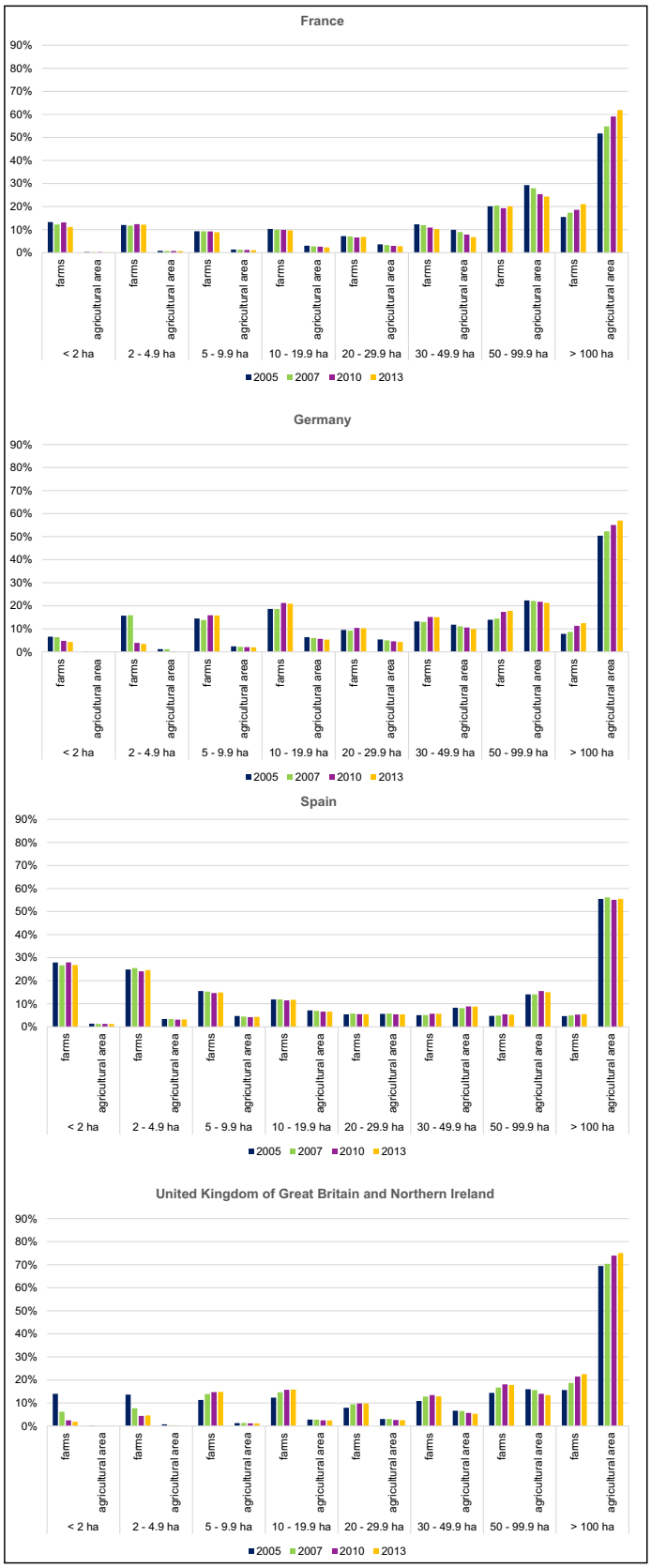

Fig. 7. Farmland distribution over time in select European countries, 2005–2013. Source: European Commission, 2019.

The evidence presented bears important policy implications. The stark differences between family farms and small farms makes clear the importance of how we are defining different types of farms and our distinguishing among the different types of farms when engaging in policy discourse and decision making. The policies needed for the largest farms in the world are most certainly

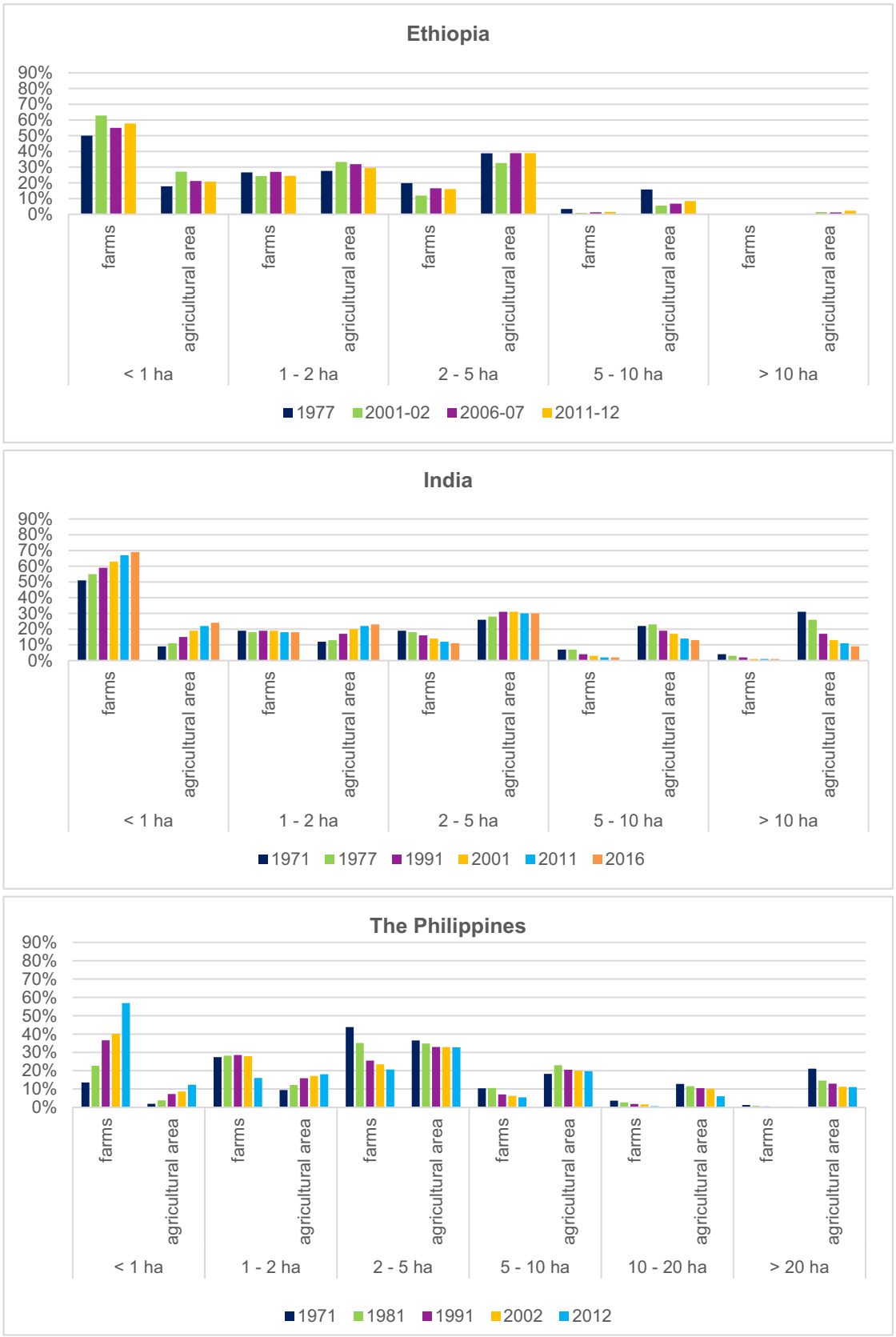

Fig. 8. Farmland distribution over time in Ethiopia, India and the Philippines from the 1970s. Sources: FAO, 2013; Government of India, 2015, 2019; Philippine Statistics Authority, 2015; The Federal Democratic Republic of Ethiopia, 2012, 2007.

Table 2
Average farm size by region in hectares, 1960–2010

	1960	1970	1980	1990	2000	2010
East Asia and the Pacific (11)	1.9	1.9	1.8	1.6	1.5	1.5
Middle East and North Africa (11)	7.7	5.8	4.7	4.0	3.4	3.6
South Asia (5)	2.6	2.3	2.0	1.6	1.2	1.4
Sub-Saharan Africa (26), excluding South Africa	2.9	2.4	2.0	1.5	1.6	1.6
Europe and Central Asia (5)	33.0	34.1	36.1	35.7	39.7	41.5
Latin America and the Caribbean (28)	70.4	61.3	63.0	50.2	46.4	39.8
High-income European countries (28)	12.3	13.9	15.0	16.5	18.4	21.3
Other high-income countries (15)	86.0	87.8	97.0	115.5	99.1	77.9

Note: number of countries in parenthesis. Source: FAO (2013) and agricultural census reports from the 2010 census round (see "Sources: Agricultural census reports and information consulted" in the web Appendix B).

Table 3
Average farm size by income group in hectares, 1960–2010

	1960	1970	1980	1990	2000	2010
Low-income countries (19)	2.1	1.8	1.7	1.2	1.0	1.3
Lower-middle-income countries (26)	3.1	2.7	2.3	1.9	1.6	1.7
Upper-middle-income countries (35)	29.6	28.3	30.4	25.7	24.8	23.8
High-income countries (43)	39.8	41.9	45.8	50.8	53.1	53.7
World (129)	15.7	12.9	12.2	9.4	8.1	7.3

Note: number of countries in parenthesis. Source: FAO (2013) and agricultural census reports from the 2010 census round (see "Sources: Agricultural census reports and information consulted" in the web Appendix B).

different from those needed for resource poor and land-scarce farms in the developing world. It is imperative that we refrain from interchangeably using the terms family farms and small farms. It would be helpful to distinguish among different types of family farms, including distinguishing among family farms of different sizes.

Looking at all types of farms will be critical to achieving several Sustainable Development Goals, including those of eradicating poverty (SDG 1), achieving Zero Hunger (SDG 2), addressing inequalities (SDG 10) and achieving more sustainable production patterns (SDG 12). Should we wish to address, for example, reducing poverty and improving livelihoods, we must consider smaller farms in developing countries. Furthermore, in efforts towards achieving more sustainable production patterns, it will be difficult, if not impossible, to hold large scale and corporate agriculture accountable for the negative externalities of their production (for example on the environment), if we focus mostly on smallholders and small family farms.

Information on farms as presented in this paper can support the SDG monitoring framework. Target 2.3 of the Zero Hunger goal (SDG 2) makes reference to the need of doubling, by 2030, the agricultural productivity and incomes of small-scale food producers, family farmers, and pastoralists and fishers, among others, but it does not make explicit reference to farms. Its indicator 2.3.1, though, measures the volume of production per labor unit by classes of farming/pastoral/forestry enterprise size. This indicator can particularly benefit from datasets presented in this paper.

Nonetheless, improvements to agricultural censuses are necessary in order to take better stock of all types of farms and their socioeconomic characteristics, and thus generate key evidence for SDG monitoring and policy making more generally. As noted in the introduction, FAO has promoted the World Programme for the Census of Agriculture since 1950, by providing governments with guidance on standard methodology and contents for their agricultural census. As part of such work, governments have provided FAO with census reports and tabulated results from their agricultural censuses. In addition to tabulated results, countries have started providing FAO with farm level data (also referred to as microdata) and it will be a significant contribution if more countries follow suit. In an effort to collect and disseminate such data, FAO has recently launched the Food and Agriculture Microdata (FAM) Catalogue; a platform designed for the cataloging and release of census and survey microdata (FAO, 2020b). Initiatives such as the 50x30 are improving data available for measuring SDGs in low and lower middle income countries, while AGRIS is helping collect the data needed to measure SDGs in other countries (FAO, IFAD, World Bank, USAID, BMG, 2020 and GSARS, 2017). That data may also facilitate our better answering the question of how much of the world's food is produced by what size and what type of farms. Until then, estimates shown in this paper may provide insight.

Agricultural censuses themselves can also be improved in many ways and many of these are suggested in the guidance FAO has provided for the 2020 round of the agricultural census (FAO, 2015). Since information about labor on farms is limited, it would be useful for more agricultural censuses to provide estimates of the ages of farm workers and agricultural holders. Furthermore, information on farm labor tends to be limited to permanent workers and household members such that more surveys should include information on seasonal or temporary hired labor. Country level data on both production and a measure of agricultural land by farm type and commodity would make it possible to have more accurate estimates of the share of food and agriculture produced by family farms as well as farms of different sizes. Survey modules that cover non-household farms should ideally be carried out in countries where the agricultural census has been limited to household farms only. For this to happen, additional funding is necessary and FAO's uniform methodology (FAO, 2015, 2018) must be followed.

Credit authorship contribution statement

Sarah K. Lowder: Conceptualization, Methodology, Data curation, Writing - original draft. **Marco V. Sánchez:** Conceptualization. **Raffaele Bertini:** Methodology, Data curation.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.worlddev.2021.105455.

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