Urbanization and Farm Size in Asia and Africa: Implications for Food Security and Agricultural Research[1]

Forthcoming in *Global Food Security*
This version revised 25 June 2013

William A. Masters[2], with Agnes Andersson Djurfeldt, Cornelis DeHaan, Peter Hazell, Thomas Jayne, Magnus Jirström and Thomas Reardon

1. Introduction and Motivation

This study is a synthesis of evidence assembled for the Consultative Group on International Agricultural Research (CGIAR), in a foresight workshop on "Trends in Urbanization and Farm Size in Sub-Saharan Africa and South Asia: Implications for Agricultural Research", held 25-26 January 2013 at Tufts University in Boston, USA. The synthesis was written by the first author, through a consultative process commissioned by the Independent Science and Partnership Council (ISPC) of the CGIAR, using five background papers presented and discussed at the foresight workshop. This article thus reflects the contributions of all workshop participants, which included 25 experts on various aspects of agricultural development from both the social and biophysical sciences.

By design, the foresight workshop aimed to elicit a wide range of views, which we seek to reconcile here. This synthesis paper is neither a summary of workshop proceedings, nor independent work. Instead, the synthesis is based entirely on data and concepts presented at the workshop and discussed afterwards, reconciling the participants' diverse views into a single narrative. The resulting synthesis is based entirely on workshop documents and discussion, but does not replace the five background papers each of which is available separately on the ISPC website.[3] Paper authors and workshop participants were deliberately selected to bring in diverse and often conflicting perspectives. This document does not repeat those divergent arguments, but provides an original synthesis from the first author's point of view.

[1] The paper was written by the lead author, based on background papers by the other authors listed above, and contributions from foresight workshop participants Awudu Abdulai, Deborah Balk, Derek Byerlee, Cheryl Doss, Ken Giller, Margaret McMillan, Clare Narrod, Gerald Nelson, Kei Otsuka, Carl Pray, Agnes Quisumbing, Bharat Ramaswami, Anita Regmi, Steve Staal, and Steve Wiggins. Many thanks are also due to Kenneth Cassman, Doug Gollin and Tim Kelley for guidance and suggestions from the ISPC, and to Dana Goldman and Nadira Saleh for assistance during the foresight workshop. A draft version of this synthesis was presented at the 7th meeting of the Independent Science and Partnership Council (ISPC) of the CGIAR on 25-27 March 2013 in Cali, Colombia.

[2] Contact author: W.A. Masters, Department of Food and Nutrition Policy, Tufts University, Friedman School of Nutrition Science and Policy, 150 Harrison Ave., Boston MA 02111. William.Masters@tufts.edu, http://sites.tufts.edu/willmasters.

[3] All background papers and project details are available at www.sciencecouncil.cgiar.org/sections/strategy-trends.

2. Urbanization and Rural Population Growth

Average farm sizes, in the sense of total land area per farmer, are ultimately dictated by a region's farm population. Total land area available for agriculture changes relatively little from year to year, and in developing countries most rural people are farming, so trend changes in average farm size are ultimately driven by changes in total population net of migration to towns and cities. Aggregate trends in the rural and urban population for Africa and Asia over the foresight study period are shown in Table 1:

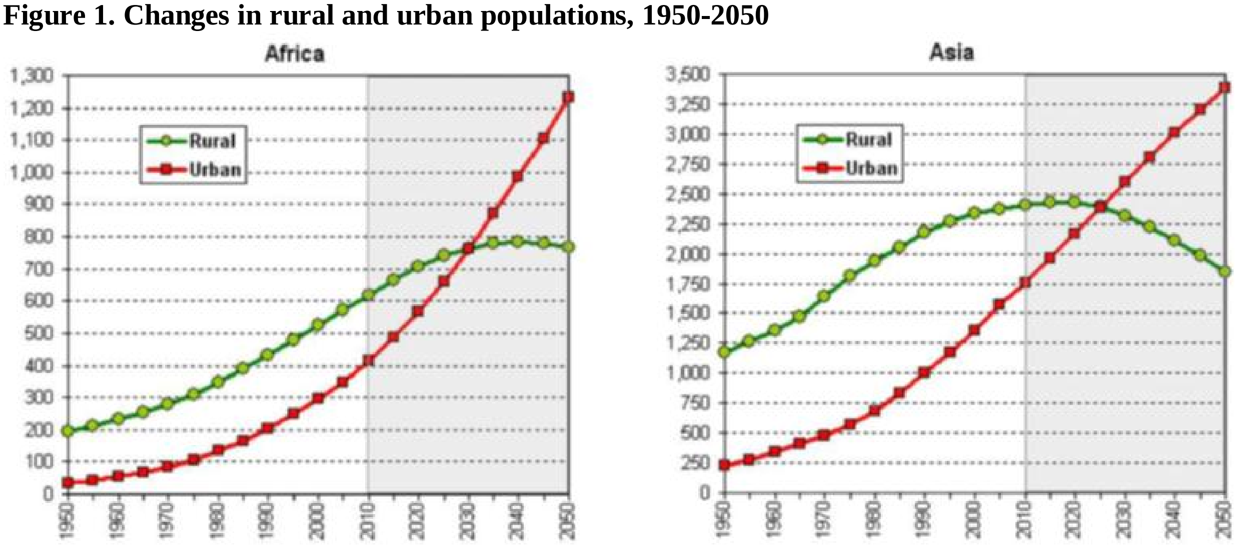
Table 1: Trends in rural and urban populations, 1970 to 2050, Africa and Asia

	Population (millions)				Average annual rate of change (%)		
	1970	2011	2030	2050	1970-2011	2011-2030	2030-2050
Total Population							
Africa	368	1,046	1,562	2,192	2.55	2.11	1.69
Asia	2,135	4,207	4,868	5,142	1.65	0.77	0.27
Urban population							
Africa	87	414	744	1,265	3.82	3.09	2.65
Asia	506	1,895	2,703	3,310	3.22	1.87	1.01
Rural population							
Africa	282	632	818	927	**1.97**	**1.35**	**0.63**
Asia	1,629	2,312	2,165	1,833	**0.85**	**-0.35**	**-0.83**

Source: Hazell 2013, from UN data.

Our focus is on the results shown above in bold, indicating continued high rates of growth in the rural population of Africa, with lower growth that will soon become a decline in the rural population of Asia. These same data are used to illustrate year-to-year changes rural as opposed to urban populations in Figure 1 of Thom Jayne's background paper:

Figure 1. Changes in rural and urban populations, 1950-2050



Source: Jayne 2013, from UN data in Parnell and Walawege (2011).

The UN urbanization estimates shown in Table 1 and Figure 1 have been subject to great scrutiny by demographers such as workshop participant Deborah Balk (2013), often using geographic techniques as described in the background paper by Agnes Andersson Djurfeldt and Magnus Jirström (2013). Both Hazell and Jayne recognize that the way these estimates were constructed severely limits how they should be interpreted. In particular, the UN data are derived from national censuses in which the definition of "urban" or "rural" residence varies widely, so the densities cannot readily be compared across countries. There may also be systematic differences across continents in statistical procedures. As noted by Deborah Balk and by Andersson Djurfeldt and Jirström, taking account of increasingly accurate remote-sensing and geocoded survey data to count seasonal migrants, slum dwellers and the residents of smaller secondary towns and cities, it appears likely that Africa is actually more rural and less urbanized, relative to Asia, than these data suggest. In addition, Deborah Balk's workshop comments explained how these estimates rely on linear projections between census years, rather than structural demographic models. Taking account of gender and age-specific fertility, mortality and migration rates, it is likely that Africa's rural populations have actually grown more rapidly over time, relative to Asia's, than these data suggest.

Other data sources are not sufficiently comprehensive to replace the UN data shown in Table 1 and Figure 1, but they do indicate that these estimates are likely to be a conservative lower bound on the actual Asia-Africa differences in rural population growth and hence average farm sizes. Clearly, during the first three or four decades of CGIAR activity, both Africa and Asia experienced a gradual decline in the total land available per rural worker. There is great diversity within each continent, but long-term trends are driving the average farmer in both Africa and Asia to apply more labor on existing land, increasing the payoff from the development and adoption of labor-using, land-saving techniques such as new seeds and agronomic techniques. African farmers experienced much steeper declines in land per worker than Asian farmers, making year-to-year production growth per worker harder for them. Africa's distinctive demographic transition also involved much larger increase in child dependency ratios. Gender differences in responsibilities for both food supply and child care made these trends impose a particular burden on women, worsening the cost of unequal access to resources and market opportunities.

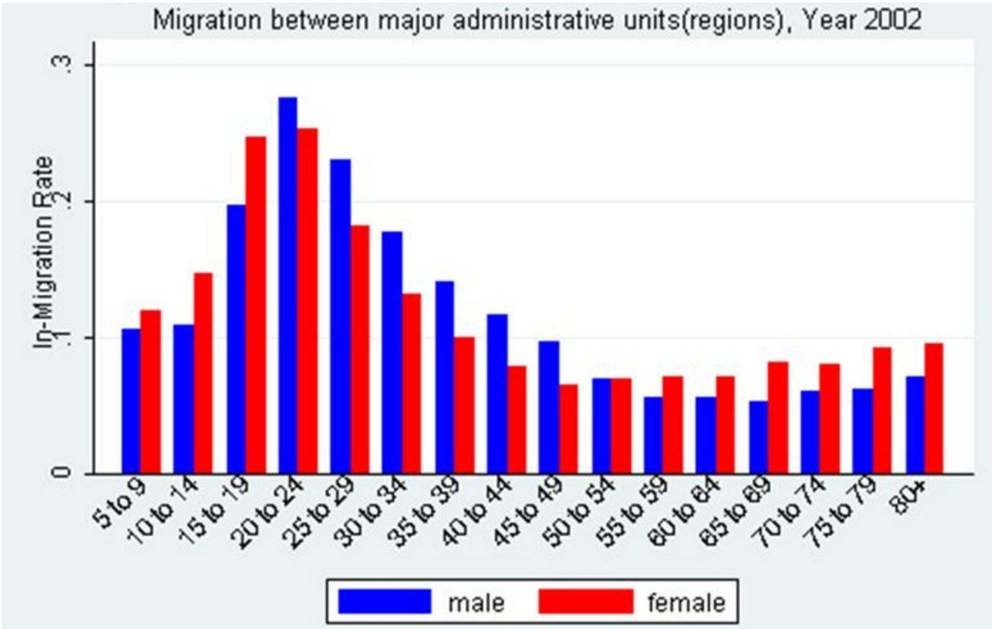
Looking ahead, the shaded area of Figure 1 shows that rural population has or will soon reach its peak in Asia, but will continue to rise for several more decades in Africa. Some of this change is due to demographic structure, notably the rapid aging of Asia's rural populations relative to Africa's, and some of it is due to net migration. Local conditions across and within countries influence the exact timing of this turning point in rural population density, but the average Asian farm size already has or will soon begin to rise, as some rural households cultivate land released by neighbors whose workers have stopped farming. This rise in total land and other rural resources available per farmer, combined with the increased number and proximity of urban consumers, farm input suppliers and product marketing firms, ensures that the average farm size in Asian agriculture already or will soon involve increased output per farm and the kind of commercial dynamism described in detail by Tom Reardon in his background paper, even as the average African farm size faces several more decades of worsening land scarcity as described by Thom Jayne.

Farm size trends at any given location may vary around the continent-wide trend, and that trend itself may not be precisely known, but the general direction of demographic change remains among the most predictable forces driving farmers' choice of technique and hence the agricultural research priorities of CGIAR centers and other public or private-sector organizations pursuing agricultural innovation. Across Asia, an increasing share of farm households have already or will soon experience an end to farm-size decline and begin to acquire larger areas, making it newly attractive for them to adopt land-using, labor-saving techniques with additional equipment and more capital per worker. In contrast, most of Africa will continue to experience falling average farm sizes for several more decades.

The predictability of these trends arises from demographic momentum and the persistence of age-specific mortality, fertility and migration rates, combined with economic constraints on the growth rate of urban employment. As shown in the background paper by Andersson Djurfeldt and Jirström (2013), Annex Tables A1 and A2, poverty rates are almost universally higher in rural than in urban areas. The gap in average incomes and living standards is typically larger in poorer countries, and drives a steady flow of net migration from rural areas into towns and cities. For any given worker, migration is risky and often seasonal, so net migration rates are smaller than gross flows which include seasonal and circular movements between various rural and urban locations. Migration itself is costly and urban opportunities are often highly gendered and age-specific, requiring particular levels of human, social and financial capital. For all these reasons, the rural-urban income gap tends to narrow over time but it is not eliminated until countries reach very high levels of income.

The age and sex specific nature of migration is illustrated in Figure 2 from the workshop presentation of Deborah Balk, showing how access to urban livelihoods in Uganda is concentrated among those who are 15 to 30 years old. Females migrate at somewhat younger ages than males, and migration rates drop sharply after the age of 30, as urbanization proceeds slowly and drives change in the gender and age composition of the growing rural population.

Figure 2. Urban in-migration rate by age and gender in Uganda



Source: Balk 2013, from Uganda census data.

In summary, rural population growth determines change in total land area per rural worker and hence average farm sizes, in predictable ways that can be taken into account when setting agricultural research priorities. Most notably, farms in Africa will continue to become smaller and more labor-intensive on average, even as that trend reverses in Asia where farms will become larger and more capital-intensive. Underneath these averages, however, there is great heterogeneity within agriculture as described in the following section.

3. Agricultural Heterogeneity and the Distribution of Farm Sizes

Rural population growth determines *average* farm size changes, in the sense of total land and other natural resources available per farm household. Most farm households also have significant nonfarm activities at all farm sizes and level of farm income, and their mix of those activities vary widely by location. Crop and livestock activities also vary widely, and farmers typically do not spread out evenly across all available land as detailed in Thom Jayne's background paper. Even within cultivated zones there is great diversity of farm sizes, as illustrated in Table 2. Across all of these surveys, the smallest quartile of farms are generally much smaller than farms in the largest quartile ones, with about one-tenth as much land per capita. This reflects differences in land quality, household wealth and many other variables.

Table 2. Land distribution among smallholder farms in selected African countries

Country (year of survey)	(a) Sample size	(b) Mean farm size (ha)	(c) Farm Size (hectares per capita)					(d) Gini Coefficients		
			Mean	Quartile 1	2	3	4	Land per household	Land per capita	Land per adult
Kenya, 1997	1146	2.28	0.41	0.08	0.17	0.31	1.10	0.55	0.56	0.54
Kenya, 2010	1146	1.86	0.32	0.07	0.12	0.25	1.12	0.57	0.59	0.56
Ethiopia, 1996	2658	1.17	0.24	0.03	0.12	0.22	0.58	0.55	0.55	0.55
Rwanda, 1984	2018	1.20	0.28	0.07	0.15	0.26	0.62	--	--	--
Rwanda, 1990	1181	0.94	0.17	0.05	0.10	0.16	0.39	0.43	0.43	0.41
Rwanda, 2000	1584	0.71	0.16	0.02	0.06	0.13	0.43	0.52	0.54	0.54
Malawi, 1998	5657	0.99	0.22	0.08	0.15	0.25	0.60	--	--	--
Zambia, 2001	6618	2.76	0.56	0.12	0.26	0.48	1.36	0.44	0.50	0.51
Mozambique, 1996	3851	2.10	0.48	0.1	0.23	0.4	1.16	0.45	0.51	0.48

Source: Kenya: Tegemeo Rural Household Surveys, Tegemeo Institute, Nairobi. Ethiopia: Central Statistical Authority surveys 1995 and 1997, Government of Ethiopia. Rwanda:1990 Ministry of Agriculture Survey. Malawi: Profile of Poverty in Malawi, 1998, National Economic Council, 2000. Zambia: Central Statistical Office Post-Harvest Surveys. Mozambique: 1996 Ministry of Agriculture and Rural Development (MADER) Smallholder Survey.
Note: Numbers for Ethiopia, Rwanda, Mozambique, and Zambia, including Gini coefficients, are weighted to be nationally representative.

Reprinted from Jayne (2013)

The surveys in Table 2 cover multiple years for Kenya and Rwanda, showing their progressive decline in average farm sizes. Their farm-size distributions also became more unequal over time, as shown by the increase in their Gini Coefficients. Indeed this increased dispersion in farm sizes is so great that in Kenya from 1997 to 2010, and in Rwanda from 1990 to 2000, farms in the largest quartile actually became *larger* over time, leaving even less land per farm for the others. It is not clear how or why the largest farms in these surveys were able to acquire even more land even as other farms became smaller. Violent conflict and political power may have played a role, along with commercial purchases by nonresident owners using earnings from other sectors to buy farmland.

For most field crops, the most cost-effective farm sizes are those cultivated by resident farmers in a household enterprise, relying primarily on self-motivated family members. Such family farms have generally displaced colonial plantations, collective farms or any kind of state- and investor-owned farming operation, and then once agriculture becomes a household enterprise, family farming generally remains the dominant mode of production even in very high-income countries as explained below. Economically optimal farm sizes thus rise and fall with the number of rural households relative to land area, implying that optimal farm sizes across Africa will continue to fall for several more decades until agricultural population density reaches its peak. Only when agricultural population density begins to decline will optimal farm size will turn upward as it has in other regions with earlier demographic transitions.

The dominance of family farming, and hence the link between rural population density and optimal farm size, is driven by the difficulty of supervision and offsite management for many field crop operations such as planting, fertilizing, irrigation or drainage and pest or weed control. Whether such tasks are done correctly is often unobservable, because they require location-specific response to changes in natural conditions that intervene to influence the harvest. Self-motivated family members therefore do these tasks more effectively at lower cost. Family enterprises continue to dominate crop production as incomes rise, even in the US, Australia or Japan, with farm sizes varying in proportion to land productivity and other factors.

Farms with many nonfamily workers typically arise mainly in settings with state-restricted labor and land rights, such as serfdom and slavery, or colonialism, socialism and state capitalism. Such systems have often built up large farms, often using subsidized capital as well as restricted land and labor. Almost all of these have been broken up in recent decades, and been replaced by more efficient family enterprises as soon as labor is freed to move onto their own purchased, rented or sharecropped land. The major exceptions are crops that must be processed on the farm or in close coordination with the harvest, notably tea, sugar and oil palm, or crops that are produced under highly uniform, controlled conditions such as flowers and high-value vegetables, or many livestock operations. In these cases, scale economies in machinery and buildings and marketing or processing activities are sufficient to outweigh any costs of labor supervision, resulting in efficiencies at larger farm sizes.

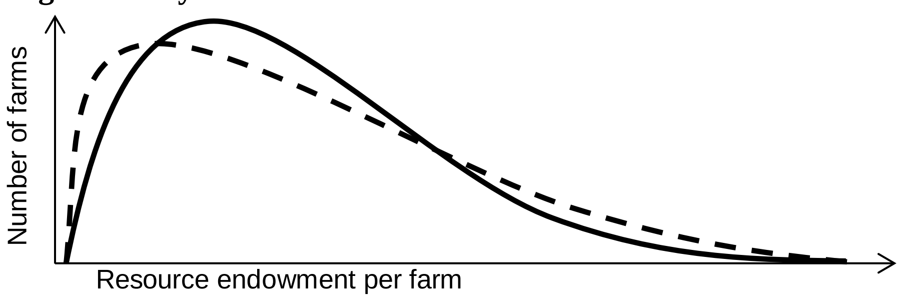
For most field crops, the difficulty of supervising nonfamily workers ensures that the most efficient, least-cost farm size is that which suits a family enterprise, and hence moves in line with rural population densities. For livestock, as detailed in Cees de Haan's background paper, the situation is very different: herd and flock sizes are influenced not by rural land/labor ratios as much as by wage rates relative to the capital costs of animal ownership, so herd sizes have risen sharply in Asia and are already rising in Africa despite the decline in farm sizes for Africa's field crops. The difference between most field crops and most livestock arises in part because supervision of hired labor is relatively easier for animal care, particularly those raised under controlled conditions such as pigs and poultry; dairy remains the major livestock sector where size of operation is typically tied to the scale of a family enterprise.

Future technologies could change the economics of farm size. At the technology frontier in the U.S., Australia, Brazil and elsewhere, software and hardware is being introduced in an effort to replace farmers' real-time judgments and make it possible for investor-owned farms using hired managers to compete with family operations. Key elements of field crop automation include GPS units on auto-steer tractors, using soil sensor data to control variable-rate input applicators. Laser-leveling and other investments can make the environment more uniform, but farmers still need to make adjustments on the fly in response to real-time weather. The profitability of precision agriculture is therefore dependent not only on the cost of capital relative to labor, but also on the quality of the algorithm that adjusts input use in response to changing conditions. Even if these automated field operations are commercialized successfully in some settings, therefore, the willingness and ability of self-motivated farmers to adapt themselves and learn quickly how to farm elsewhere ensures that much of agriculture will remain dominated by family enterprises – including particularly in Africa.

Ken Giller's workshop discussion provided an agronomic perspective on the challenges brought by falling farm sizes in the African setting, particularly for the most resource-poor farm households. He used a stylized distribution shown by the solid line in Figure 3 to explain how the smallest farms, whether measured in terms of land, livestock or other resources, often cluster near the lower bound of survival. The modal farm will be somewhat above that minimum size, while a small number of larger farms enjoy much bigger resource endowments. With the important exception of crops that offer scale economies from on-farm processing, even the large farms remain family enterprises. As shown by the comparison of columns (b) and (c) in Table 2 above, they average four to six family members per farm, irrespective of cropped area across countries. As these farms' land area shrinks, research must focus on increasingly labor-intensive, yield-increasing methods for agroecological management of their crops and livestock.

The changes over time in quartile averages and Gini Coefficients shown in Table 2 can be illustrated in Figure 3 by a change from the solid to the dashed distribution. The dashed curve is wider at both tails, as the many small farms have shrunk even as the few large farms grow. An extreme version of this story has occurred in Zambia and elsewhere in recent decades, with prime land along transport routes being ceded to a few very large farms similar to those developed during the colonial era in Zimbabwe, South Africa and other countries with latifundia-type agriculture. These farms use capital-intensive irrigation and machinery, much of which is operated by hired managers and farm workers, even as most Zambian farm households cultivate smaller and smaller areas in the agricultural hinterland.

Figure 3. Stylized distributions of farm size



Source: Adapted from Giller (2013)

In situations where the largest farms acquire their land for reasons other than economically efficient production, they typically incur higher total costs per unit of output than the modal farms due to greater capital requirements and the difficulty of supervising hired labor. It may be difficult to distinguish such inefficiencies from economically efficient changes in farm size, since heterogeneity among farm households typically gives rise to variation in access to resources and market opportunities, especially in dynamic zones with increased commercialization. Heterogeneity among firms in their growth rates is typical of economic activity. What is distinctive about agriculture is only that the total area of land available is fixed, and each farm is typically a family enterprise using agriculture as a residual employer alongside nonfarm opportunities. As a result, when large farms grow for whatever reason, those displaced who cannot find work in other sectors remain in agriculture, further reducing the sizes of the smallest farms. Any increase in the number of very large farms is often accompanied by an increase in the number of very small farms, and it is entirely possible for a country's average farm size to rise while the modal or median farm size shrinks, or vice-versa.

When farm-size distribution changes as illustrated in Figure 3, the expansion of large farms uses land that would otherwise be available for small farms and the most resource-poor households with the least access to nonfarm employment may find their farms becoming inefficiently small. Productivity of the smallest farms may be particularly low when farm sizes have declined too fast for agricultural techniques to adapt (perhaps due to recent demographic change), or small farms have become increasingly feminized (perhaps due to differential migration), with high child dependency (as in much of Africa) or a rapidly aging workforce (as in much of Asia), or the households face violence or socially exclusion (often for reasons of caste or ethnicity); all of these socioeconomic changes can compound the agroecological challenges of soil degradation, water depletion, climate change and other biological constraints that are likely to be especially severe in the disadvantaged regions that are least likely to attract private investment for farm-size expansion.

In summary, demographic and other changes have altered both average farm sizes and their distribution. To inform agricultural research by the CGIAR and other organizations, our principal forecast is that Africa's most resource-poor farmers will become even more impoverished, unless they are equipped with new seed varieties and agronomic techniques adapted to their newly constrained circumstances, as well as policies and institutions that promote economic inclusion and market access. At the other end of the farm size distribution, the largest farms in Africa may become even larger, but their growth comes at the expense of smaller farms with the potential for inefficiency as well as inequity at both ends of the farm-size distribution. Only where migrants can settle previously uncultivated lands or some kind of machinery provides sufficient scale economies to justify labor supervision can African farm sizes grow in an economically efficient manner, whereas for much of Asia average farm sizes have already begun to expand in keeping with that region's falling rural population density.

4. Agricultural Commercialization and Input Use in "Dynamic" and "Hinterland" Zones

The trends in farm size described in the previous section are driven by long-term demographic changes in land-to-labor ratios, with important implications for the kinds of innovation that farmers are seeking. Urbanization and economic development also brings a very different set of changes to the farm, through demand for farm outputs and opportunities for increased commercialization and input use. As dynamism spreads to previously hinterland areas, even a shrinking farm can become increasingly commercialized. This often involves specialized capital investment, for example when developing a zero-grazing dairy, a fruit orchard or a vegetable garden, but can also occur for staple food production. The workshop comments of Carl Pray described how input supply firms combine innovations from public sources such as the CGIAR with their own innovations to produce locally adapted techniques.

Tom Reardon's background paper describes in detail how this works in the dynamic agricultural zones of Asia, where falling transaction costs and increased capital availability per worker have led to a remarkable "quiet revolution" in food supply chains within rural areas and from there to urban consumers. He estimates that half to two-thirds of Asia's food production is already fully commercialized, in the sense of being produced for intermediaries serving urban consumers. This has major implications for agricultural technologies, as it facilitates a sharp increase in the use of purchased inputs and specialized capital often provided by small, local agribusinesses. Many activities previously done by family members on the farm are increasingly purchased from others, including contract providers of custom services such as land preparation or harvesting and threshing. The transformation also changes market institutions. For example, Reardon documents the rise of competing cold stores that buy potatoes for urban markets in India, Bangladesh and China. These have broken historical monopolies, improved farmers' terms of trade, and created a competitive market for inputs and farm credit as well. Meanwhile, in the "hinterland" areas with high transaction costs, access to land, credit, inputs and product markets may remain interlinked and subject to a wide variety of market failures.

Dynamic zones of increased commercialization arise around African towns and cities, along their main transport and communications routes. But the magnitude of transformation is much smaller, as most African farm households are still operated as semi-subsistence operations, often as net buyers of crops that they also grow themselves. Table 3 below from Jayne (2013) illustrates the degree of commercialization observed for maize in East and Southern Africa.

Table 3. Net maize sales by farm size in Kenya, Malawi, Mozambique and Zambia

Country	% of sample	Net maize sales/adult equivalent (kgs)	Farm size (hectares)	Value of household assets (US dollars)	Total household income/adult equivalent (US dollars)
Kenya (2010)					
Large sellers	26.9	668	3.7	4 032	984
Small sellers	11.5	57	1.9	2 491	488
Occasional buyers	37.3	-5	1.8	2 912	494
Consistent buyers	24.3	-64	1.4	1 801	471
Malawi (2007)					
Large sellers	2.2	542	2.0	1 915	258
Small sellers	4.7	50	1.8	298	75
Occasional buyers	48.2	-4	1.4	248	60
Consistent buyers	44.9	-93	1.1	195	50
Mozambique (2005)					
Large sellers	10.4	na	3.3	194	312
Small sellers	16.7	na	2.7	120	151
Occasional buyers	41.1	na	1.8	92	119
Consistent buyers	32.8	na	1.8	121	103
Zambia (2008)					
Large sellers	19.5	556	3.0	1 756	488
Small sellers	7.5	59	2.1	642	241
Occasional buyers	42.4	-4	1.6	454	182
Consistent buyers	30.7	-88	1.4	642	252

Source: Adapted from Jayne (2013)

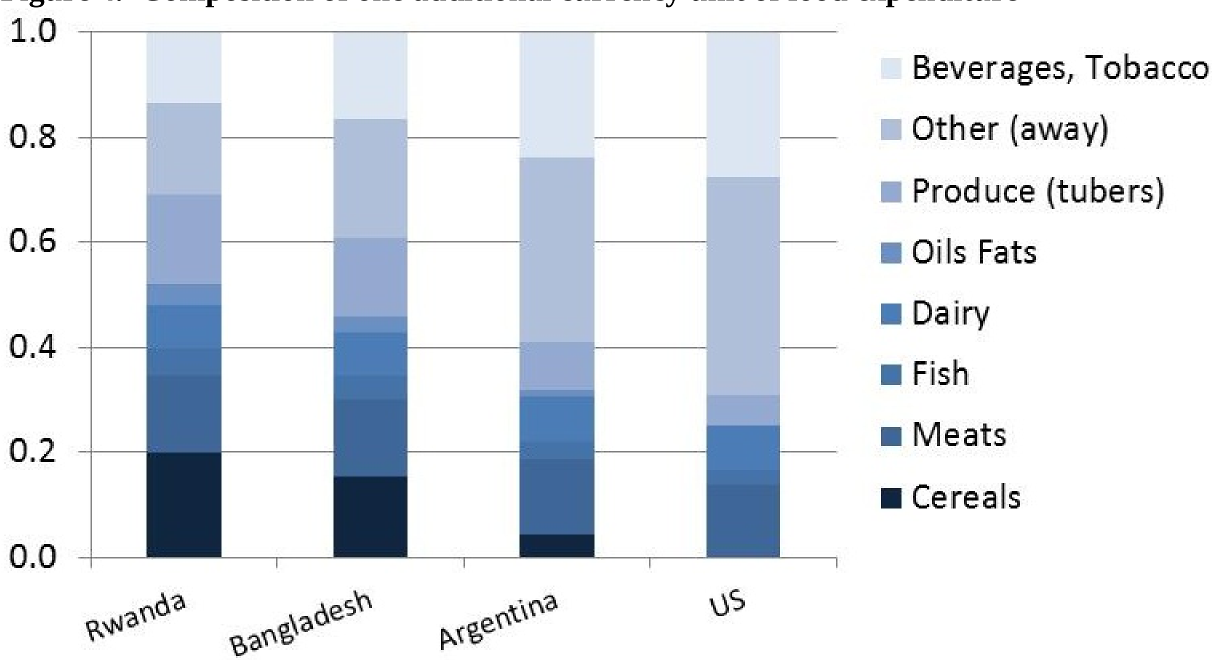
Table 3 suggests that in these four countries, the most commercialized maize sellers are the largest farms. This need not be the case for all crops, to the extent that agricultural research successfully develops intensification techniques suited to African farmers' growing conditions and shrinking farm sizes. To the extent that these innovations serve urban consumers for high-value and differentiated products, their adoption domain may be limited to dynamic zones with low cost of transport to towns and cities. But Table 3 reveals that a very large market is offered by the on-farm consumption of rural households themselves, when they lack enough land to meet their needs. Developing and disseminating the seed varieties and agronomic techniques needed to achieve a declining real cost of food for everyone, including net food buyers in isolated rural areas, is a key pathway to impact for CGIAR research.

5. Dietary Change and Food System Transformation

The commercial dynamism described in the previous section generally follows transportation routes, reducing transaction costs and opening up low performance but high potential zones for increased specialization and trade. Along with changes in the mix of inputs comes a dietary transition in the mix of outputs from lower- to higher-value foods associated with income growth, including the highly visible transformation of food systems from traditional products to branded goods in supermarkets.

Dietary change across types of food is illustrated in Figure 4, from the workshop presentation of Anita Regmi. This chart shows how income growth drives consumer expenditure towards higher-value foods and other products. At low levels of income such as Rwanda, about 20% of any increase in spending on food goes towards increased consumption of cereal grains. An additional 20% goes towards meat and fish. About 10% is spent on dairy, oils and fats, and about 20% is spent on produce including tubers. The remaining 30-35% is split between food away from home and beverages or tobacco.

Figure 4. Composition of one additional currency unit of food expenditure

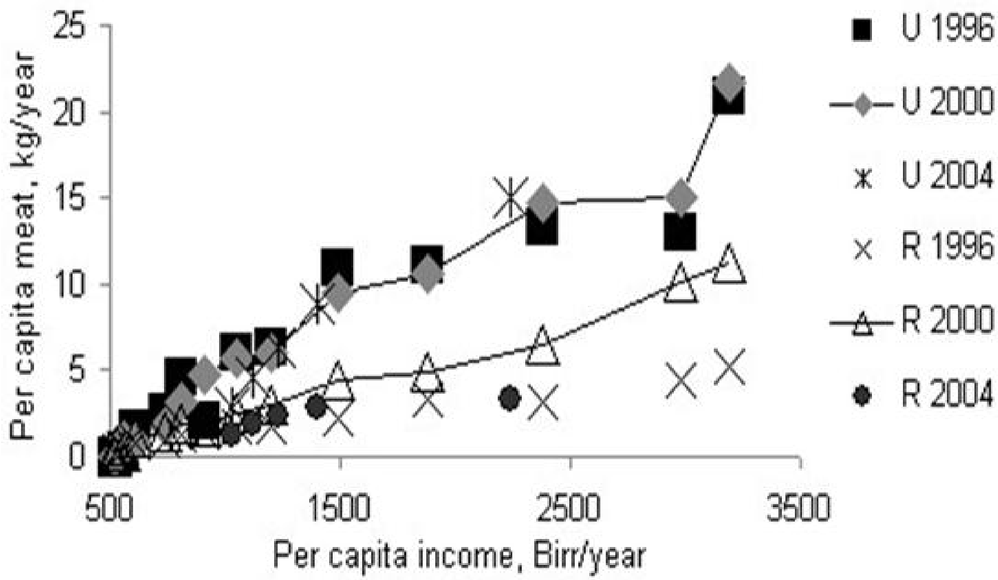


Source: Regmi (2013), from Muhammad et al. (2011).

The data shown in Figure 4 reveal how food prices are particularly important for reducing extreme poverty, as price declines driven by agricultural productivity growth release funds for other things. The total of cereals, meats, fish, dairy, oils and fats, and produce including tubers takes up 60% of incremental spending at the income level of Bangladesh, but only 40% at the level of Argentina, and 30% at the level of the United States.

For priority-setting in the CGIAR and other agricultural research organizations, a particularly important question is how quickly demand for animal-sourced foods is likely to grow. This matters both for the absolute level of demand for cereal grains and oilseeds, and for the degree to which cropland is devoted to commodity crops for animal feed as opposed to other crops for human consumption. Cees de Haan's background paper addresses this question in detail, using evidence such as Figure 5 from Ethiopia.

Figure 5. Meat consumption and income in Ethiopia by urban/rural residence, 1996-2004



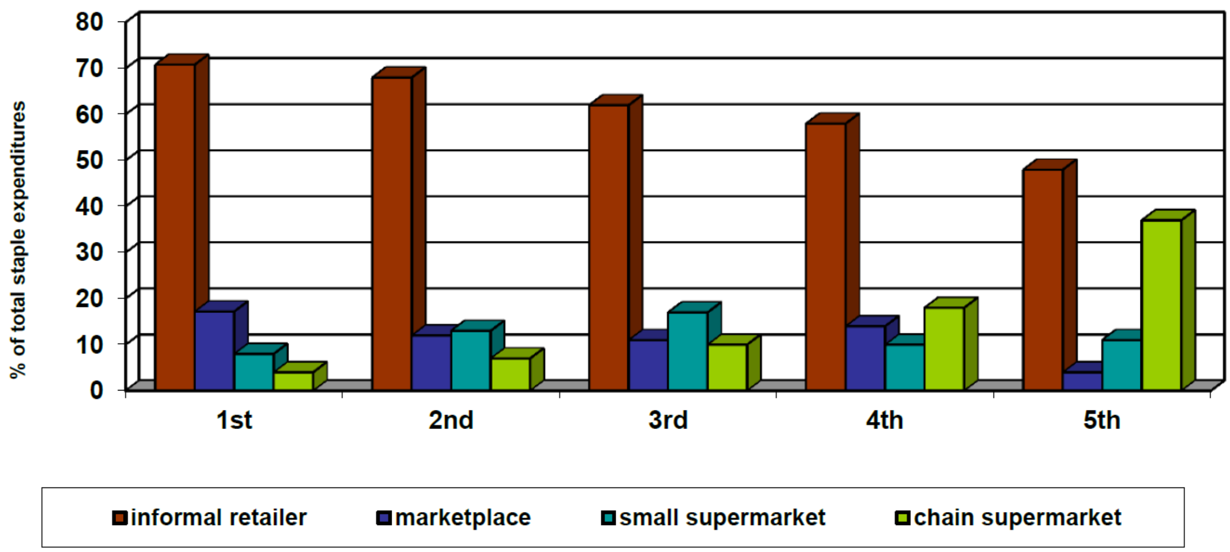
Source: De Haan (2013), from Betru and Kawashima (2009).

Figure 5 reveals three distinct patterns. First, confirming the previous result from Anita Regmi, higher incomes are associated with higher meat consumption. Second, for any given level of measured income, meat consumption is higher in urban areas. Third, controlling for income and location, the only visible shift over time appears for the higher income rural households, who consume more meat in 2000 and 2004 than they did in 1996. These results suggest a fairly stable, predictable pattern ahead, as urbanization and increased incomes both drive higher meat consumption and the need for sharp increases in animal feeds within Africa as well as in Asia.

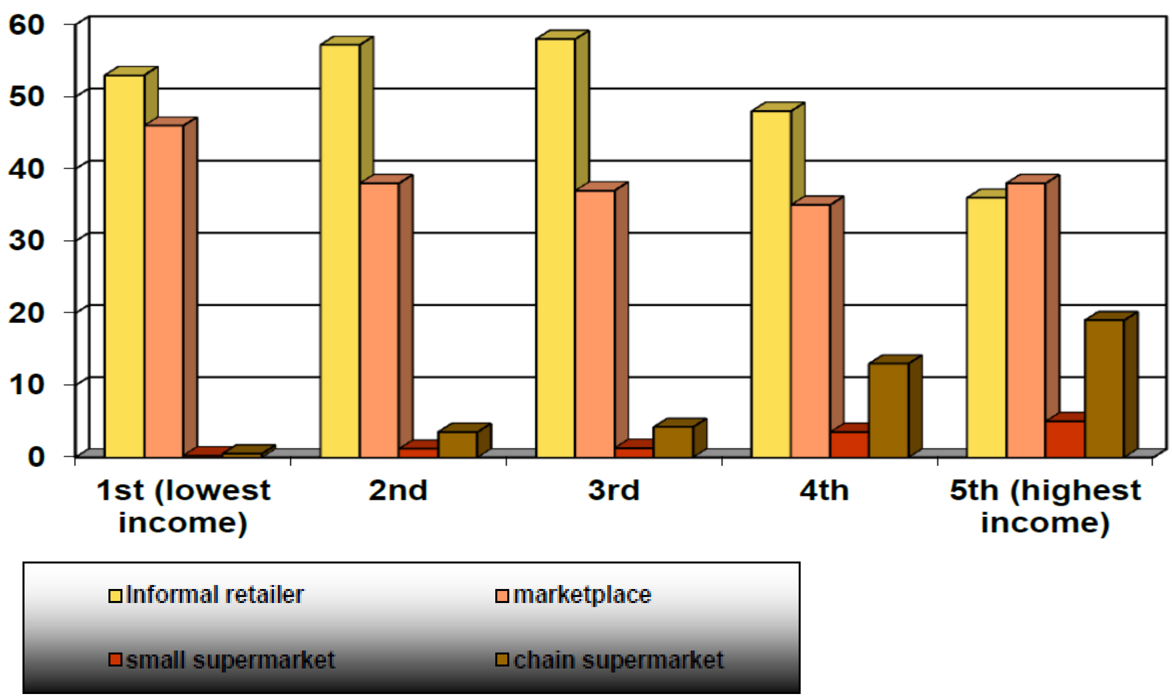
A final dimension of food system transformation is the "supermarket revolution", characterized by increasing consumer demand for the uniformity, packaging and convenience offered by formal retail outlets as opposed to traditional markets. Reardon had documented the extraordinary speed and depth of this transformation across Asia and Latin America. Figure 6 from Jayne shows the much smaller penetration achieved in African cities, where even the wealthiest quintile of consumers continue to buy most of their staple foods from informal retailers and open markets as opposed to any kind of supermarket.

Figure 6. Consumer expenditure shares on staple food products by retailer type

Panel A. Nairobi, Kenya, 2003



Panel B. Four cities of Zambia, 2008



Source: Jayne (2013).

6. From Foresight to Recommendations: Conclusions for Agricultural Research Priorities

The goal of this foresight study is to anticipate trends and variability in farming conditions that will affect the adoption and impact of agricultural innovations, so as to draw recommendations for the CGIAR and its public or private-sector partners in international agricultural research. The CGIAR's strategic objectives of reduced poverty, increased food security, improved nutrition and sustained resource management can be met only by anticipating these changes, and then acting in ways that exploit the CGIAR's distinctive features in partnership with the many other organizations that pursue similar objectives in various settings. The study aimed to help the CGIAR make best use of its unique strengths in global public goods provision, using international exchange of materials and knowledge to meet farmers' rapidly changing, location-specific needs. Although the research itself is almost entirely in the public domain, the resulting innovations are then disseminated through both public and private sector channels to achieve population-level reductions in poverty and improvements in food security, nutrition and sustainability.

To help agricultural innovators achieve their objectives, the foresight study considered both trends and variation in terms of broad categorizations offered by Tom Reardon and Peter Hazell. Reardon's distinction between "dynamic" and "hinterland" areas focuses primarily on commercialization, which is typically driven by transaction costs and access to urban product demands as well as input provision. Hazell's categorization combines that with farm size and propensity to shift labor out of agriculture entirely. Here we use a slightly modified version of Hazell's terminology, modified in accordance with discussion among the workshop participants. The categories we propose follow from the previous discussion in this synthesis report:

- "Subsistence" farming households are low-income, semi-autarkic or net food buyers. They are characterized by a low use of purchased inputs and low sale of farm outputs. They are often women, may be geographically isolated, nearly landless, frequently ill, socially excluded or have particularly insecure property rights, and are pursuing food and cash crop production largely because they have very limited other options to meet household needs.
- "Commercial" farmers are now or could soon be closely linked to product value chains and input suppliers, and sufficiently specialized to separate their farm production decisions from household consumption preferences. They have or will soon invest in significant fixed capital for their farm, and may also have access to credit markets through which to borrow additional funds as well as land rental or purchase opportunities with which to expand their farm operation. Although they are "farming as a business", it is not their only business. Across all kinds of countries, most commercial farmers also have significant nonfarm income.
- "Transitional" farm families aim to leave farming. They may have high or low levels of farm income, but their principal objective is to develop the skills and assets needed to exit from agriculture. Farm earnings are often needed to help them build human capital, start nonfarm enterprises or migrate successfully.

Table 4 shows how farms of each type might transition over time, from left to right across each row. These desirable objectives to be supported by agricultural research strategies would, for example, help a subsistence farmer become either a commercial farmer or move to nonfarm activity. A commercial farmer might be helped to intensify their operation on their existing land, or to acquire additional plots and become a larger farm, and in a few cases they might sell a profitable operation and exit from the sector. Finally, a transitional farmer might be helped to become commercial, or they might use agricultural earnings to exit from farming. The relative size of these three groups will vary by country context, and it is often very difficult to predict which household will end up in each category, but in all cases higher agricultural productivity would help the household achieve its desired transitions.

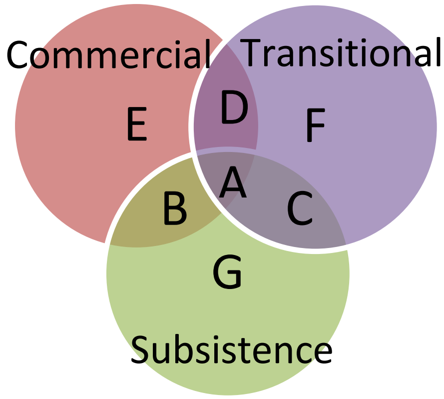
Table 4: Transition matrix from small farm groups

Initial type of farm (Period t)	**Desired Transition** (Period t+1)		
	Commercial	*Large Farm*	*Nonfarm*
Subsistence	X		X
Commercial	X	X	X
Transitional			X

Note: X = desired transition
Source: Adapted from Hazell (2013)

To pursue the transitions identified in Table 4, CGIAR priorities might target a wide range of economic zones, agroecological regions, or crop and livestock systems. Figure 7 illustrates how a priority-setting exercise might begin to choose among them. The purpose of this diagram is primarily to help identify research priorities in category A that could benefit all three kinds of farmers. Such targets would have by far the greatest uptake and social impact, driving both poverty reduction and economic growth. Investments that focus on poverty reduction might also aim for priorities in category B, C, G or F that reach subsistence and transitional farmers with safety nets and social protection as well as new technology, whereas investments that focus on economic growth might aim for categories D and E. Some investments could focus on category B, to help rural residents find off-farm work on nearby farms, but the magnitude of hired labor in global agriculture is not large enough for this to be a major route out of poverty on a population scale.

Figure 7. Potential benefits of agricultural research accruing to different types of farms



Source: Hazell (2013)

The dissemination of agricultural research is likely to proceed first and fastest through the dynamic zones with low transaction costs, particularly through private-sector input supply firms. As detailed in the workshop comments by Carl Pray, they may conduct some of their own private R&D, which often uses material and techniques introduced by the CGIAR and its public sector partners. Technologies whose fixed cost of initial introduction is financed by serving farmers in dynamic zones can often then be adapted and supplied to more remote locations as well. The CGIAR should also aim to develop and facilitate dissemination of innovations aimed directly at subsistence, resource-poor farmers in hinterland areas, both to promote their transition to commercialization and also to reduce their poverty and facilitate their eventual exit from agriculture. In these settings, a small absolute increase in output or reduction in land, labor and other inputs corresponds to a large proportional increase in productivity.

International agricultural research and policy change is a powerful instrument for sustainable poverty reduction among all types of farmers, particularly when it spreads productive innovations that are scale-neutral and divisible to reach small farms. Many other interventions are also needed for economic development, but the agricultural research toolkit is particularly powerful precisely because the fruits of international agricultural research complement those interventions, and make them more worthwhile. For example, institutions and infrastructure to support market development are more productive when farmers can adopt productivity-enhancing innovations – and likewise, social protection and safety nets are more affordable when agricultural productivity is higher, and environmental sustainability is easier to achieve when innovations to reduce resource use and limit negative externalities are available. Furthermore, although the name and structure of the CGIAR highlights its cross-country focus on international exchange of knowledge and materials, the ultimate goal is always highly location-specific and tailored to a particular group of farmers. As emphasized in this report, heterogeneity within countries calls for differentiated strategies, with research activities guided by the systematic use of large-scale geocoded datasets. The CGIAR's international mandate gives it a particular comparative advantage in this kind of "big data" research, including simulation modeling and impact assessment.

In summary, the spread of agricultural dynamism enables many farmers to use international agricultural research all the more effectively, even as those left behind in hinterlands need it all the more urgently, while new measurement tools allow agricultural researchers to target their work all the more precisely.

Our specific conclusions and recommendations for the CGIAR are as follows:

(1) Urbanization and economic development have made global agriculture increasingly differentiated, creating new opportunities for millions of farmers in commercially dynamic zones, even as millions more remain isolated in less accessible hinterlands. Heterogeneity is closely tied to gender barriers and social exclusion as well as geographic isolation. ***Research priorities for the CGIAR must be increasingly tailored to this diversity, helping to spread agricultural dynamism while lifting the productivity of lagging farmers.***

(2) Agriculturally dynamic zones often extend quite far from towns and cities, along transport routes that carry a "quiet revolution" in the commercialization of crops and livestock. In these areas, farms are served by specialized agribusinesses that exploit scale economies in provision of farm inputs and marketing of farm outputs, even as crop production remains dominated by household enterprises with both farm and nonfarm activities. ***Research priorities in dynamic zones should recognize the***

intermediary role of agribusinesses, and provide the new technologies and institutional innovations needed for competition among the diverse firms that serve farm households.

(3) Isolated hinterland zones offer agricultural households limited opportunities for either farm or nonfarm activity, due to low productivity and high transaction costs. The boundaries between dynamic and hinterland zones can shift rapidly as opportunities expand, but those who live in lagging areas often face worsening poverty due to population growth and resource depletion including climate change. With limited resources other than labor, hinterland farmers often have no choice but to farm even as they remain net food buyers, using income from scarce nonfarm employment to supplement what little they can grow. Thus, **CGIAR** ***research priorities in hinterland zones should recognize those farmers' resource constraints, and provide the new technologies and institutional innovations needed to raise the productivity and stability of their agricultural systems, reducing poverty and supporting a gradual transition towards dynamic agriculture and off-farm employment.***

(4) Farm sizes vary widely within each area, reflecting heterogeneity among households as well as differences in land quality. For most crops, cost-effective farm sizes are that of a household enterprise that balances the cost of supervising employed workers against any sources of scale economies such as mechanization. Households bring a variety of assets to their family farm, leading to a distribution of cropped area and livestock herd sizes that shifts over time in each location. The poorest households not only have the smallest farms and herd sizes, but often also suffer from gender bias and many other kinds of discrimination. Meanwhile, the wealthiest or most politically powerful landowners may accumulate so much land that its productivity falls, due to the high cost of supervising labor over large areas. Investor-owned farms with hired managers typically succeed only in crops that are processed on the farm such as tea, sugar and oil palm, or in operations where labor skills are more readily observed by the employer such as greenhouses or livestock, since remote monitoring of field operations remains costly despite the spread of GPS devices and variable-rate technology***. For most CGIAR mandate crops, research tailored to the needs of household-sized operations for self-motivated family farmers has the highest probability of commercial success.***

(5) Changes in average farm size depend on rural population growth, which in turn depends on natural increase minus out-migration from rural areas. During economic development, out-migrants generally earn higher incomes than those left behind, but urban employment is rationed by the cost and risk of migration as well as demand for urban goods and services. As the rate of natural increase slows, rural populations eventually reach their peak and begin to decline, so average farm sizes can begin to increase. Asia as a whole has already or will soon reach this turning point, but for almost all of Africa it is decades away. A related transition occurs in livestock based in part on the cost of labor relative to capital as well as veterinary technologies, driving increases in herd and flock sizes in Asia that are now starting to be seen in Africa. ***CGIAR research should anticipate the effect of demographic trends on average farm sizes; in most African countries farm sizes will continue to shrink for several more decades, so innovations that are land-saving and readily divisible to serve smaller plots will have the highest probability of commercial success, whereas in much (but not all) of Asia innovations to increase farm size are increasingly attractive. For livestock, the emphasis should be on increasing efficiency with respect to land, water and other resources, as well as the mitigation of health and environmental externalities.***

(6) Targeting agricultural innovations increasingly requires "big data" statistical tools. The conclusions of this study are framed at the aggregate continental level, but they emphasize heterogeneity among zones (in the distinction between "dynamic" versus "hinterland" areas), within any given zone (in the distribution of farm sizes and commercialization levels), and over time (through shifts in the farm-size distribution that result from demographic trends) and by gender or other social group (often due to differences in economic opportunity and bargaining power). To operationalize these conclusions, ***CGIAR programs should continue to expand their investment in spatial models of global climate, land use, migration and economic development, to predict changes in what types of crop or livestock innovations are needed at each location to sustainably increase productivity and reduce poverty.***

REFERENCES CITED

WORKSHOP BACKGROUND PAPERS

Agnes Andersson Djurfeldt and Magnus Jirström, 2013. "Urbanization and Changes in Farm Size in Sub-Saharan Africa and Asia from a Geographical Perspective: A review of the literature." Background paper for the ISPC Foresight Study on Farm Size and Urbanization, revised 6 February 2013. Available online at http://www.sciencecouncil.cgiar.org/sections/strategy-trends.

Cornelis (Cees) de Haan, 2013. "Urbanization and Farm Size Changes in Africa and Asia: Implications for livestock research." Background paper for the ISPC Foresight Study on Farm Size and Urbanization, revised 12 February 2013. Available online at http://www.sciencecouncil.cgiar.org/sections/strategy-trends.

Thomas Jayne, 2013. "Urbanization and Farm Size Changes in Sub-Saharan Africa: Implications for agricultural research." Background paper for the ISPC Foresight Study on Farm Size and Urbanization, revised 27 February 2013. Available online at http://www.sciencecouncil.cgiar.org/sections/strategy-trends.

Peter Hazell, 2013. "Urbanization and Farm Size Changes in Africa and Asia: Cross regional comparison and implications for agricultural research." Background paper for the ISPC Foresight Study on Farm Size and Urbanization, revised 15 February 2013. Available online at http://www.sciencecouncil.cgiar.org/sections/strategy-trends

Thomas Reardon, 2013. "The Economics of Urbanization, Farm Technology, and Farm Size Distribution in Asia." Background paper for the ISPC Foresight Study on Farm Size and Urbanization, revised 20 March 2013. Available online at http://www.sciencecouncil.cgiar.org/sections/strategy-trends.

DISCUSSANTS' COMMENTS CITED

Deborah Balk, 2013. Discussant's comments at the ISPC Foresight Study Workshop on Trends in Urbanization and Farm Size in Sub-Saharan Africa and South Asia: Implications for Agricultural Research, held 25-26 January 2013 at Tufts University in Boston, USA. Contact information: deborah.balk@baruch.cuny.edu.

Ken Giller, 2013. Discussant's comments at the ISPC Foresight Study Workshop on Trends in Urbanization and Farm Size in Sub-Saharan Africa and South Asia: Implications for Agricultural Research, held 25-26 January 2013 at Tufts University in Boston, USA. Contact information: ken.giller@gmail.com.

Carl Pray, 2013. Discussant's comments at the ISPC Foresight Study Workshop on Trends in Urbanization and Farm Size in Sub-Saharan Africa and South Asia: Implications for Agricultural Research, held 25-26 January 2013 at Tufts University in Boston, USA. Contact: pray@aesop.rutgers.edu.

Anita Regmi, 2013. Discussant's comments at the ISPC Foresight Study Workshop on Trends in Urbanization and Farm Size in Sub-Saharan Africa and South Asia: Implications for Agricultural Research, held 25-26 January 2013 at Tufts University in Boston, USA. Contact information: aregmi@ers.usda.gov.

OTHER SOURCES OF DATA CITED

Shawel Betru and Hiroyuki Kawashima, 2009. Pattern and determinants of meat consumption in urban and rural Ethiopia. *Livestock Research for Rural Development, vol. 21, art. 143.* www.lrrd.org/lrrd21/9/betr21143.htm.

Andrew Muhammad, James L. Seale, Jr., Birgit Meade, and Anita Regmi, 2011. "International Evidence on Food Consumption Patterns: An Update Using 2005 International Comparison Program Data." USDA ERS Technical Bulletin No. 1929, March 2011 (59 pages).

Susan Parnell and Ruwani Walawege, 2011, "Sub-Saharan African Urbanisation and Global Environmental Change." *Global Environmental Change* 21, Supplement 1 (Dec. 2011): S12–S20.

Annex 1: Agenda for ISPC Foresight Study Workshop on
Urbanization and Farm Size in Developing Countries: Implications for Agricultural Research
Tufts University, Boston, 25-26 January 2013

WORKSHOP AGENDA AND LIST OF BACKGROUND PAPERS*

Friday 25th January

08:00 *Continental breakfast*
08:30 Welcome and Introductions -- **Ken Cassman**
08:40 Chair's opening remarks -- **Will Masters**
08:45 Urbanization & Changes in Farm Size in Asia -- **Tom Reardon**
09:15 Lead discussants: **Steve Wiggins, Bharat Ramaswamy**
10:00 Urbanization & Changes in Farm Size in Africa -- **Thom Jayne**
10:30 Lead discussants: **Margaret McMillan, Agnes Quisumbing**
11:10 *Coffee Break*
11:30 Urbanization & Changes in Farm Size -- **Agnes Andersson Djurfeldt & Magnus Jirström**
12:00 Lead discussants: **Awudu Abdulai, Anita Regmi**
12:40 *Lunch*
13:45 Changes in the structure and size of livestock herds/husbandry in Asia & SSA -- **Cees de Haan**
14:15 Lead discussants: **Clare Narrod, Steve Staal**
14:55 Urbanization & Changes in Farm Size in Asia & SSA -- **Peter Hazell**
15:25 Lead discussants: **Derek Byerlee**, **Deborah Balk**
16:05 *Coffee Break*
16:20 Respondents' panel – **Ken Giller, Jerry Nelson, Carl Pray, Cheryl Doss**
17:20 ISPC Panel –**Ken Cassman, Timothy Kelley, Doug Gollin**
18:00 Open discussion: key issues emerging, and questions for day 2 – **Will Masters**
18:30 Adjourn
19:30 *Workshop dinner*

Saturday 26th January

8:30 *Continental breakfast*
9:00 Authors' panel – **T. Reardon, T. Jayne, A. Andersson-Djurfeldt, C. de Haan and P. Hazell**
10:00 Lead discussant—**Kei Otsuka**
10:45 *Break*
11:00 Discussion and conclusions – **Will Masters**
12:15 Wrap-up and next steps – **Ken Cassman**

**Titles and authors of background papers are underlined in the workshop agenda.*

Annex 2: Contact Information for All Workshop Participants

Coordinator/Host	
Will Masters	william.masters@tufts.edu
Authors of Background Papers	
Agnes Andersson Djurfeldt	agnes.andersson_djurfeldt@keg.lu.se
Cees de Haan	cornelis.dehaan@gmail.com
Peter Hazell	p.hazell@cgiar.org
Thom Jayne	jayne@anr.msu.edu
Magnus Jirström	magnus.jirstrom@keg.lu.se
Tom Reardon	reardon@msu.edu
Discussants	
Awudu Abdulai	aabdula@food-econ.uni-kiel.de
Deborah Balk	deborah.balk@baruch.cuny.edu
Derek Byerlee	dbyerlee@gmail.com
Cheryl Doss	cheryl.doss@yale.edu
Ken Giller	ken.giller@gmail.com
Margaret McMillan	margaret.mcmillan@tufts.edu
Clare Narrod	cnarrod@umd.edu
Jerry Nelson	g.nelson@cgiar.org
Kei Otsuka	otsuka@grips.ac.jp
Carl Pray	pray@aesop.rutgers.edu
Agnes Quisumbing	a.quisumbing@cgiar.org
Bharat Ramaswami	bharat@isid.ac.in / isid.bharat@gmail.com
Anita Regmi	aregmi@ers.usda.gov
Steve Staal	s.staal@cgiar.org
Steve Wiggins	steve-wiggins@ntlworld.com
ISPC panel	
Ken Cassman	kcassman1@unl.edu
Doug Gollin	douglas.gollin@williams.edu
Tim Kelley	timothy.kelley@fao.org
Note-takers	
Dana Goldman	dana.goldman@tufts.edu
Nadira Saleh	nadira.saleh@tufts.edu