India and Africa in the Global Agricultural System (1961–2050)

Towards a New Sociotechnical Regime?

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The asynchronous but somewhat similar agricultural trajectories of sub-Saharan Africa and Asia, especially India, are analysed over nearly a century (1961–2050). Millions of pieces of data available on the past (1961–2007) and on a plausible future (2006–50 projections by the Food and Agriculture Organization) are organised in a simple world food model where production, trade and consumption are aggregated and balanced in calories. Given the current and/or future land–labour relationships that characterise India and Africa, can these regions experience the same structural transformation that the developed countries went through, or work together towards a new sociotechnical regime by developing their own regionally differentiated labour-intensive production investments and technological capacities for economic, social, and ecological sustainability?

The views expressed in this paper are of the author's and may not be shared by the people or organisations to which he belongs.

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India and the African countries, like all other developing countries, are subservient to an overarching expectation of a sequential development trajectory, where incomes and labour shift or climb from predominantly agrarian, to industrial, to service sector-led growth, as had been the case in developed countries. Within this paradigm of "structural transformation" (Chenery and Srinivasan 1998; Herrendorf et al 2014), understood as "a necessary condition for cumulative and self-sustaining growth" (Johnston and Mellor 1961), recent insights into the development processes of industrialised countries have emphasised that growth and development in Africa would also depend heavily on public investments and regulations, and hence the capacity of the African governments to break out of the policies of the Washington or post-Washington consensus (Chang 2009, 2012). Here, the lessons from India are considered useful for Africa, with regard to agricultural and industrial policies, production investments, and technological capacities, especially agricultural research and extension. Some may disagree (for example, Pimentel et al 1973; Dawson et al 2016), but 20 years earlier, Uma Lele and Arthur Goldsmith (1989), drawing upon India's successful green revolution that lasted from the late 1960s until the early 1980s, and the role the Rockefeller Foundation played in this growth in productivity, advocated that Africa should find the same strong political will and elite commitment as in India, to develop similar technological capacities, build its science and technology personnel, and ensure appropriate production investments.

While India and Africa's development trajectories raise questions about how and when developing countries should "kick away the ladder" (Chang 2002), there are issues regarding the nature of the technology that should be promoted and its relationship with domestic land and labour, which are perhaps more pernicious and more substantively shaped by the overarching assumptions about development. In an era when we have the Alliance for a Green Revolution in Africa (Toenniessen et al 2008), India–Africa Forum Summits (April 2008, May 2011, October 2015), increasing Indian (as well as Chinese and Brazilian) investments by public- and private-sector entities in African agricultural lands (Scoones et al 2016; Cabral et al 2016; Rej and Ngangom 2015; Chakrabarty and Mishra 2016), and repeated calls for a more just, prosperous, and harmonious global community in 2050 (for example, Paillard et al 2014; Kohli 2016), this paper questions some of these fundamental

Figure 1: The Nine Regions of the Study*

Cartographic source: Articque

* See note 1 at the end of paper.

Source: Dorin (2014a, 2014b); Dorin et al (2013).

Table 1: Economic Growth (1970–2007, 2006–50)

	Annual Growth Rate (%)		Share of World GDP (%)		$/Cap/Day	
Region	1970–2007	2006–50	2007	2050	2007	2050
NAM	+2.88	+3.25	29.6	22.9	81, 7	368, 2
EU30	+2.50	+3.24	29.0	19.0	54, 1	268, 7
OCEA	+3.26	+3.62	1.7	1.3	63, 3	266, 2
LAM	+3.46	+4.57	5.9	8.1	9, 9	81, 7
ASIA	+4.52	+5.13	25.5	42.1	6, 6	65, 9
MENA	+4.06	+4.57	4.1	4.2	9, 6	50, 4
RUSS		+3.74		1.1		36, 7
EU08		+3.77		0.3		31, 8
SSA	+3.26	+3.98	1.6	1.1	2, 0	4, 8
World	+3.09	+4.06	100.0	100.0	14, 4	80, 9

(i) The 2006–50 estimates are based on the data sent to us by the FAO on 4 April 2012, with "GDP in million $." We did not apply any purchasing power parity or PPP rates to these GDP values whereas the FAO did, before presenting its "Table 2.4 GDP assumptions and implied convergence indicators" (Alexandratos and Bruinsma 2012: 38). In 2006 (2005–07 average), we find almost the same world GDP per capita "at 2005–007 exchange rates," but in 2050, we find about $80/day as compared to $38/day in Table 2.4. Similarly, according to the data received, the world GDP grows at +4.1% per annum from 2006 onwards, instead of +2.1% per annum as displayed in Table 2.4 to which FAO's PPP rates are applied.

(ii) 1970–2007 estimates based on UNSTAT (2010), total value added in 1990 US dollars.

(iii) $/cap/day (dollar per capita per day, a proxy of average income) cannot be compared between 2007 and 2050 since values are not expressed in the same unit (base year).

(iv) Regions ordered in descending order of $/cap/day projected for 2050.

(v) Estimates for RUSS and EU08 regions over 1970–2007 are not shown due to inconsistencies (former Union of Soviet Socialist Republics, which included some countries of EU08, was a single statistical unit before 1991).

(vi) For details of region groups (NAM, OCEA, LAM, etc), see note 1 at the end of the paper.

assumptions after having demarcated the long-term agricultural dynamics of sub-Saharan Africa (SSA) in the global food system over a period of nearly a century (1961–2050). The methodological originality of this work, the complete technical aspects of which are detailed in a report available in French (Dorin 2014a), relies on the quantitative, retro-prospective tool Agribiom (Dorin, Chapters 2 and 3, in Paillard et al 2014). From the scale of a nation or superior regional entities, up to that of the whole world, Agribiom expresses balanced annual volumes of production, trade and uses (for food, feed, seed, industry, etc) of human-edible calories grouped under three main categories according to their origin (plant, animal, and aquatic). These resource-use balances of edible biomass in calories are the inputs or the outputs of a simple biophysical model that connects land surfaces with populations and their consumptions through basic indicators of productivity (of land, labour, feed, etc) either observed in the past or assumed in future scenarios.

Using this tool, we demarcate and discuss here the overall agricultural and food dynamic of SSA in relation to eight other large regions of the world (Figure 1),[1] notably Asia, over a time span of almost a century (1961–2050). For the past period (1961–2007), we used several millions of pieces of national data, mostly from the Food and Agriculture Organization (FAO) (especially its "commodity balances" in tonnes: http://faostat.fao.org). For the projected period (2006–50), our reference scenario "PAB50" (Dorin 2014b) was backed by detailed national data provided by the authors of the FAO projections for 2050 (Alexandratos and Bruinsma 2012).[2] As we will see, according to these projections, Africa of the future would resemble India and other parts of continental Asia today, where the rural population and labour force in agriculture is still massive despite several decades of accelerated growth and urbanisation of the economy. Is this stunted structural transformation in continental Asia, especially India (Binswanger-Mkhize 2013), the future of Africa, where accelerated urbanisation and a high rural population growth is both predicted and questioned (Losch et al 2012)? The second section of the paper shows how such a common future is plausible and challenges the global food and agricultural system and, more generally, a development paradigm that shapes economic thought, policy-making and scientific and institutional innovations. In the first section, we start by presenting and discussing our synthesis of the FAO projections for SSA with no reference to structural transformation, employment and farm labour productivity, as in most prospective studies on world agriculture and food.

Projected African Boom

Between 2006 (2005–07 average) and 2050, the FAO expects the gross domestic product (GDP) growth of the whole SSA region to be more or less equal to the world economic growth, at about +4% per annum as against more than +5% for Asia, the highest regional rate (Table 1). In terms of demographic growth, however, SSA would by far see the highest growth, with +124% over 2006–50 as compared to +37% at the global level and only +28% for Asia (+147% in India from 1961 to 2005). SSA would also continue to increase its net cultivated areas[3] (+49% over 1961–2005 against +5% in India), with +20% over 2006–50, a level comparable to +24% in Latin America as against +4.3% globally and +1.5% for Asia. And, the average yield of plant food calories per cultivated hectare would more than double over 2006–50, with +120% as against +50% worldwide and +45% in Asia (+158% in India from 1961 to 2005). As a result of these increases in cultivated land and yield, SSA would show the highest growth in production of plant and animal calories (+164% and +185%, respectively, as against +56% and +61% worldwide, and +47% and +91% for Asia). This production performance would greatly contribute to increasing the average food calories availability per capita in SSA, above all in plant calories (+21% as against

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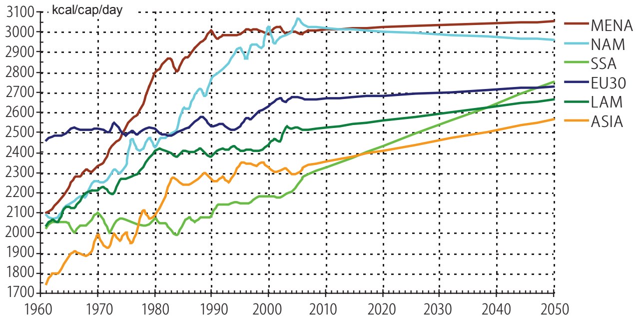
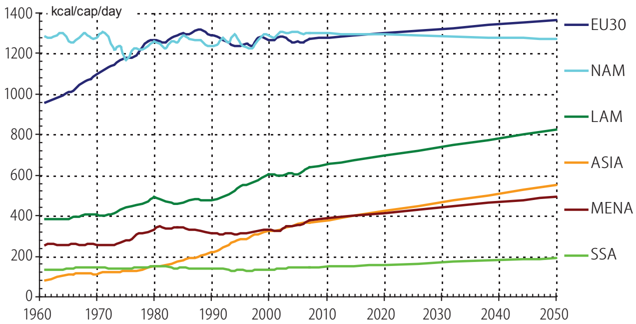
Figure 2: Food Availability per Capita in Plant Calories, 1961–2007, 2050*



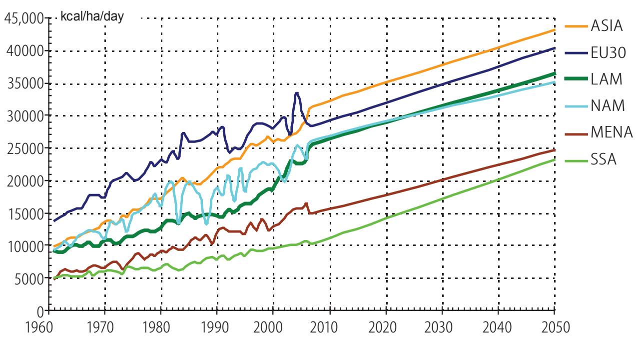
* See note 1 at the end of paper.
Source: Same as in Figure 1.

Figure 3: Food Availability per Capita in Animal Calories, 1961–2007, 2050*



* See note 1 at the end of paper.
Source: Same as in Figure 1.

Figure 4: Yield per Cultivated Hectare in Plant Food Calories, 1961–2007, 2050*



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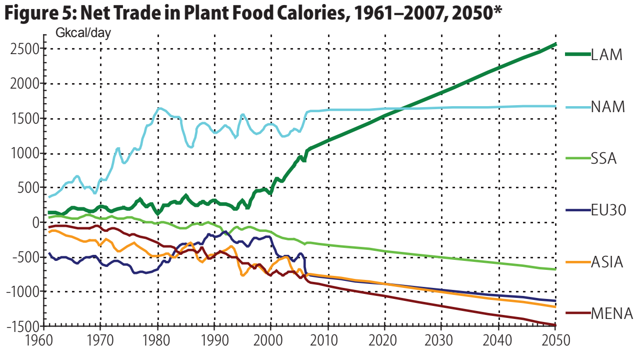
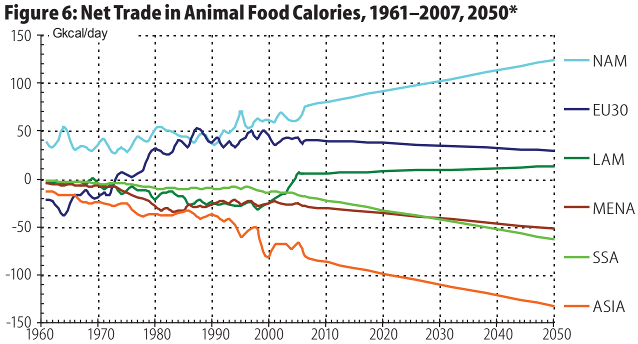
Source: Same as in Figure 1.

Figure 5: Net Trade in Plant Food Calories, 1961–2007, 2050*



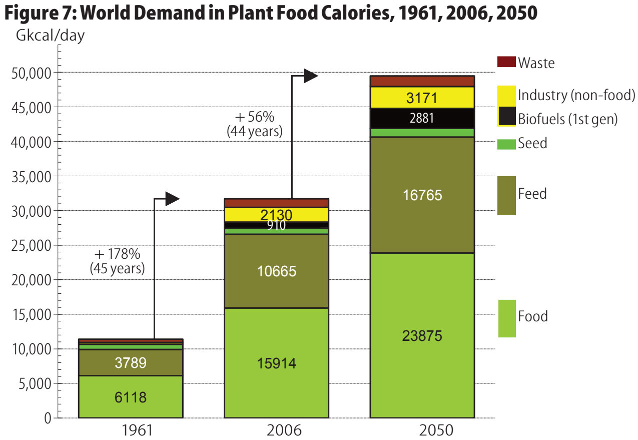
* See note 1 at the end of paper.
Source: Same as in Figure 1.

Figure 6: Net Trade in Animal Food Calories, 1961–2007, 2050*



* See note 1 at the end of paper.
Source: Same as in Figure 1.

Figure 7: World Demand in Plant Food Calories, 1961, 2006, 2050

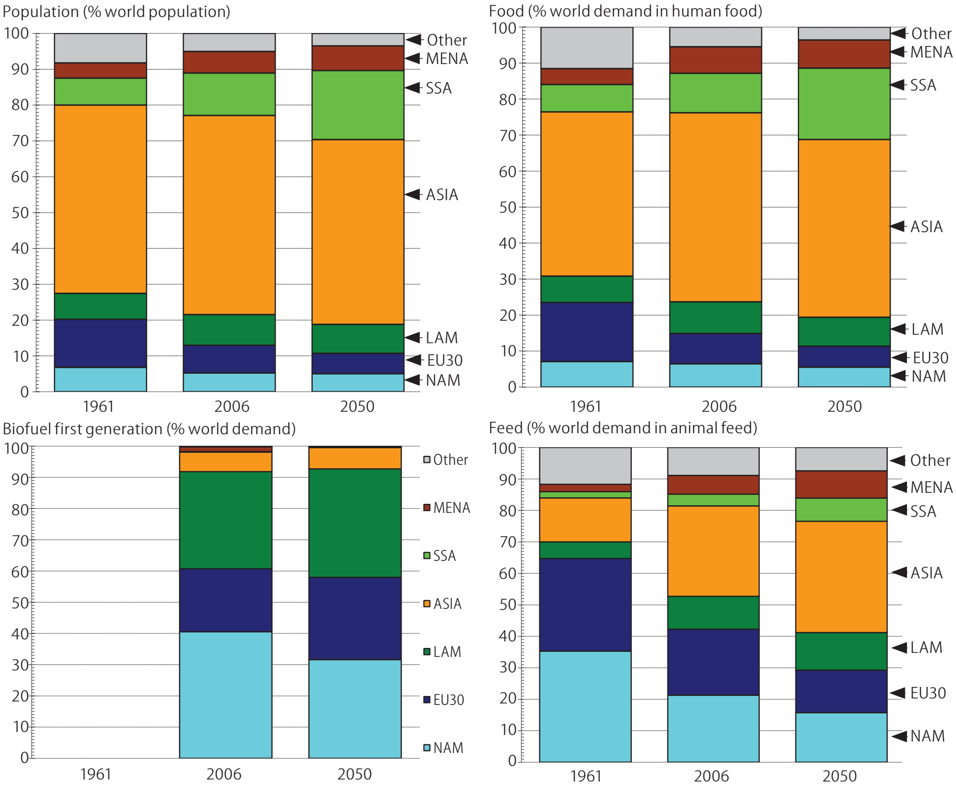


Source: Same as in Figure 1.

+9% worldwide, while it was only +12% over 1961–2006) which should be slightly higher than the global average of almost 2,700 kcal/cap/day in 2050 (Figure 2).[4]

This projected African boom should, however, be tempered. In terms of food production and consumption, SSA's starting point is extremely low (as was India's in the early 1960s) and is likely to remain so in several areas. The average food availability of animal products per inhabitant (milk, meat and eggs) would barely increase and this would widen the gap with the other regions, with less than 200 kcal/capita/day for SSA in 2050 (of a total of barely 3,000 kcal) as compared to 600 kcal/capita/day globally (550 kcal for Asia) and over 1,200 kcal in industrialised countries or countries in transition (Figure 3). The average yield of plant food calories per cultivated hectare would also remain very low at about 23,000 kcal/ha/day in 2050, far from the world average (32,200 kcal/ha including SSA) and even further from the Asian or European average (over 40,000 kcal/ha) (Figure 4). This would probably result in SSA doubling its net deficit in plant food calories (about 700 Gkcal/day in 2050, although it had a net excess of 70 Gkcal/day in 1961). In comparison to 2006, it would nonetheless remain in fourth position as a net importer of plant food calories, behind the Middle East and North Africa (MENA) region, Asia and Europe, while the other regions would continue to have a net excess of plant food calories, with Latin America clearly ahead of the others in this area (Figure 5). If we add the net trade in animal food calories (Figure 6), in 2050, the ratio of independence in food biomass for the SSA region (production/consumption, in plant food equivalent)[5] would, however, remain close to the 88% level observed in 2006 (113% in 1961). This controlled deficit can be explained by the high growth expected in African food production, the projected low increase in consumption of animal products (and hence, the demand for animal feed) and the almost zero usage of food biomass for

Figure 8: Population and Demand in Plant Food Calories by Region, 1961, 2006, 2050*



* See note 1 at the end of paper.
Source: Same as in Figure 1.

the production of first generation biofuels (unlike the American and European regions; see Figure 7 (p 7) and Figure 8 for a synthetic presentation of world consumption by use).

This is our brief and original synthesis of the FAO projections on key global issues. This synthesis has its own limitations, which are mainly related to the high level of geographical aggregation, as well as the principal unit of measurement, the food calorie. The latter has great advantages but also drawbacks, which are just as important. In particular, it does not tell us about the nutritional quality, for instance in macro and micronutrients (which can be insufficient for securing human or animal health, despite satisfactory calorific levels), or the monetary value (the value of a calorie of coffee is not the same as that of a calorie of wheat). Neither does it include products that are non-edible for humans, such as textile fibres or animal fodder (hay, straw, silage, etc). Our estimates in food calories are, in fact, only orders of magnitude; they are useful not in their absolute values, but to carry out comparisons across large geographical and temporal scales, like a "macroscope" eager to observe and anticipate the big moves of a universe.

The FAO's anticipations have limitations too. For years, this United Nations (UN) organisation has been working on and propagating agricultural and food projections at the global scale. For this exercise, it uses millions of pieces of historical data, expert opinions, forecasts established by other institutions, and a partial equilibrium model of supply and demand. As this complex exercise has no equivalent, its results have become an international reference used by a number of communities as a basis for their reflections or their own projections.

The limitations of such an exercise are, however, not always well-known or understood. We highlight several of them here, to show that the FAO 2006–50 projections are not forecasts but one possible future scenario among other possibilities.

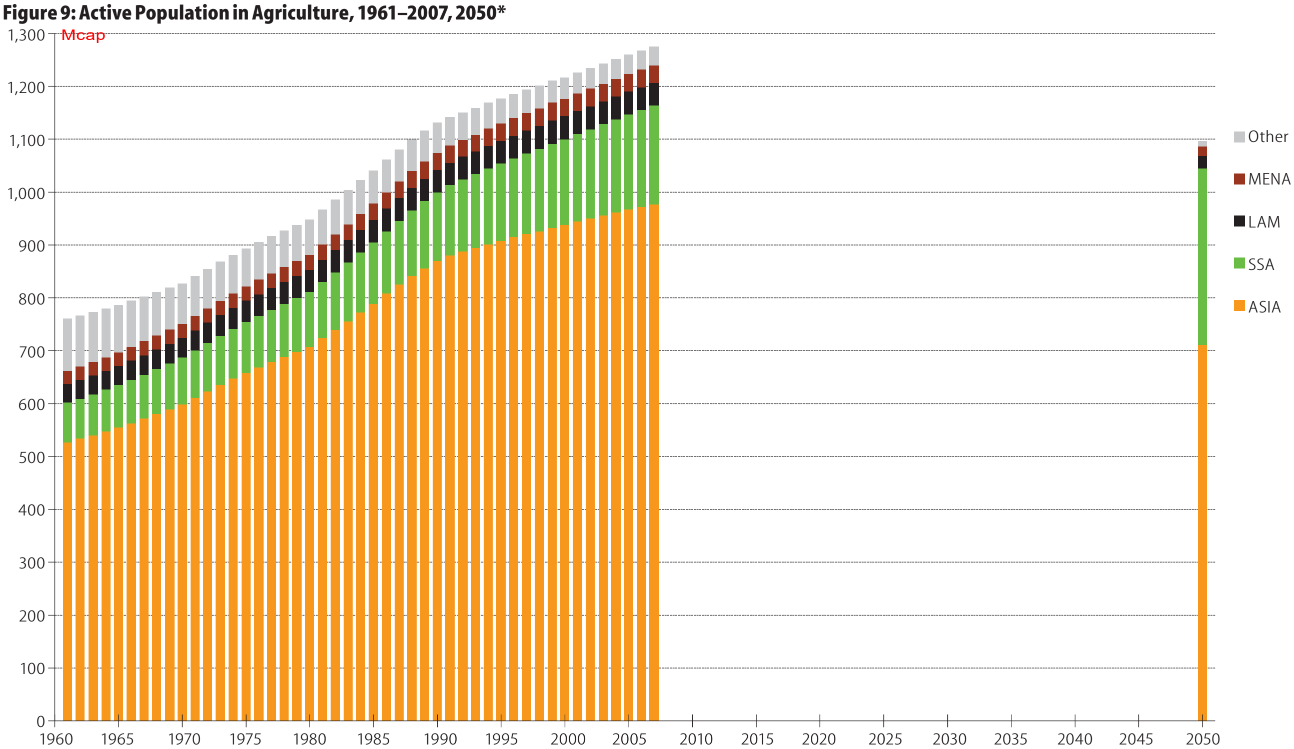
(i) Economic growth: To parameter its demand functions (using different Engel functions for the different commodities and countries), the FAO used a GDP growth scenario from the World Bank Development Prospects Group, dating from the end of the 1990s. At the time it was considered "conservative," with +4% a year over 2006–50 for SSA (almost the global rate as shown in Table 1, twice the global rate and as much as in Asia in Table 2.4 of Alexandratos and Bruinsma (2012)).[6] A few years later, with the slowdown in global growth, such a scenario could be considered "optimistic" and may be revised downwards.

(ii) Demographic growth: The FAO projections were based on the UN 2008 projections (UN World Population Prospects: The 2008 Revision), and used the "Medium-fertility" scenario. In the same demographic scenario, the UN "2012 Revision" (UN 2013) shows almost 400 million more inhabitants in SSA. Such numbers shatter some of the FAO's conclusions (Dorin 2014a: 31–33).

(iii) Animal feed: The transformation into animal food products (milk, meat, and eggs) of plant food products (cereals, oilseeds, roots, tubers, etc) via livestock farming, is little developed in the FAO exercise, although in its scenario, the main agricultural growth of the future would be driven by the demand for animal products and animal feed. A few points of difference in the transformation coefficients used by the FAO could considerably modify its final reports (Dorin 2014b: 40–42).

(iv) Demand for biofuels: Here, the FAO has only taken first generation biofuels into consideration. For the latter, it used projections until 2019, developed with the Organisation for Economic Co-operation and Development (OECD) and validated by the concerned national authorities (OCDE and FAO 2010), and assumed no further increases in subsequent projection years. For these reasons, this biofuels scenario is qualified as "limited." In any event, any biofuels scenario is very uncertain as far ahead as 2050, given the numerous ongoing interrogations in this area, at the political, economic, and technological levels (Dorin 2014b: 43–45).

Figure 9: Active Population in Agriculture, 1961–2007, 2050*



* See note 1 at the end of paper.
Source: Same as in Figure 1.

(v) Productivity of agricultural work: This area is ignored in the FAO report, although revenue from agriculture conditions the production and consumption capacities of several hundred million people throughout the world. We will return to this fundamental aspect of development in the next section.

We can add the following points to the critical ones mentioned, notably:

(i) Changes in the price of fossil fuels and its impacts on the cost of agricultural inputs and farm yields;

(ii) The effect of climate change on agricultural lands and their yield; in particular the resilience of local (also non-traded) staple crops like millets or cassava, or feed resources for livestock to new temperature and precipitation regimes;

(iii) The compatibility of the projected increases of cultivated areas, yields and animal productions with health and environmental concerns (pesticides and antibiotics, drinking water, soil fertility, climate change, biodiversity, animal welfare, etc);

(iv) Changes in the consumption of animal products, which could shift away from historical trends due to a combination of diverse factors (economic, health, environmental, ethical, etc);

(v) Changes in the demand for non-food agricultural products (fibres, rubber, construction materials, etc) that could also shift away from historical trends, particularly if the price of fossil fuels increases greatly or if restrictive climate policies are adopted;

(vi) Changes in loss or wastage rates, first between the harvest and the time it reaches the consumption units (rates currently high mainly in developing countries), then within the consumption units (mainly companies and households in developed countries);

(vii) The effects of public policies, particularly in the area of support for agriculture and biofuels, agricultural research and development, nutrition and trade in agricultural produce;

(viii) Changes in human resource capacities, and aspirations spurred by increasing investment in higher education and healthcare;

(ix) The emergence of an educated middle class with heightened democratic awareness in the highly iniquitous global economic and ecological space.

Structural Transformation, Farm Labour Productivity

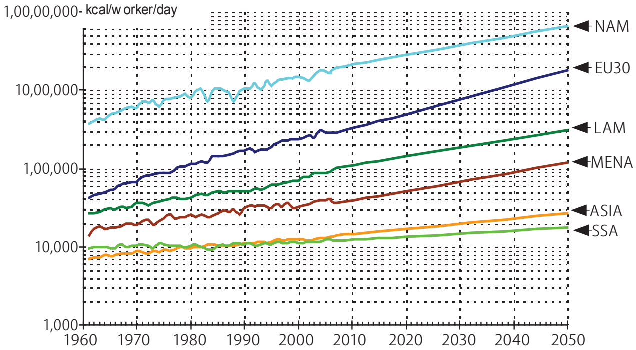
Let us now focus the discussion on an issue that today's models and projections pay too little or no attention to, despite its importance in terms of thinking about and building the future: the agricultural workforce and its income. The projections of active populations in agriculture are not displayed and discussed in Alexandratos and Bruinsma's report (2012) but were available in the files sent to us by the authors. For the SSA region they show a 2006–50 increase similar to that of Asia in the past: +81% as against a global decrease of -13%, with a drop in all the other regions, including Asia (-27% in Asia, that is, 260–280 million people presumed to have found a job outside agriculture by 2050, against +83% over 1961–2005, with +94% for India; Figure 9).

Using these data for projected active populations in agriculture is undoubtedly questionable as they are neither documented nor used by the FAO, but they were the most credible basis to continue our exercise. We combined them with our estimates in calories, and arrived at the following results.

(i) In 2050, the average labour productivity in sub-Saharan agriculture would fall below 18,000 kcal of plant food per worker per day, as compared to 1.8 million in Europe (100 times more) (Figure 10, p 10).

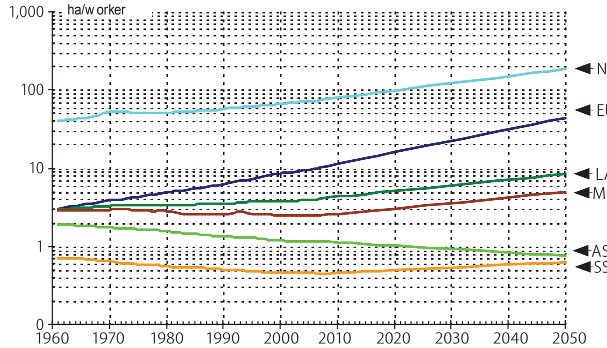
(ii) To raise this low average labour productivity to the level of Asia in 2050 (about 27,000 kcal/worker/day) would require,

Figure 10: Production of Plant Food Calories per Agricultural Worker, 1961–2007, 2050*



* See note 1 at the end of paper.
Source: Same as in Figure 1.

Figure 11: Availability of Cultivated Land per Agricultural Worker, 1961–2007, 2050*



* See note 1 at the end of paper.
Source: Same as in Figure 1.

ceteris paribus (Dorin 2014a: 34–36), the following absolute changes between 2006 and 2050, or a combination of them: (a) an increase in the cultivated area of +175 million hectares instead of +43 million in our reference scenario; (b) an increase in yield up to +24,500 kcal/ha/day instead of +12,600 kcal; and (c) an increase in the number of agricultural workers limited to +37 million instead of +150 million.

Under either of these conditions, the average agricultural labour productivity in SSA would then approach 27,000 kcal/worker/day in 2050 as in Asia. But, it would still remain the lowest in the world, and would continue to diverge instead of converging with the productivity levels of the developed regions (Dorin 2014a: 34–36). This productivity level would, for example, be 245 times lower than that of North America, where the dynamics are very different. The North American region should, in fact, continue to lose its agricultural workers (numbered slightly over 1.1 million in 2050) replacing them with increasingly impressive (and capital intensive) motorised equipment that allows the remaining farmers to exploit ever larger surfaces: almost 200 ha on average per agricultural worker in 2050, as against 0.8 ha or less in SSA and Asia (Figure 11).

Alongside this widening international gap in agricultural labour productivity in calories that seems less disputable than monetary values in PPP for instance,[7] and that higher prices or lower production costs in SSA or Asia are unlikely to counterbalance due to the magnitude of the gap, we also tried to see how the labour income gap between farm and non-farm employments would evolve within SSA in our 2006–50 reference scenario. With our own rough country estimates of total economically active populations until 2050, we came to the conclusion that this gap would widen within SSA (Dorin 2014a: 37–38), as has been the case within Asia throughout the past few decades (Dorin et al 2013; Dorin and Aubron 2016). To say the least, in a context where many workers and their families cannot find a dignified livelihood in agriculture (or elsewhere) compared to the rest of the population, high-performing economies such as the ones of Asia today risk being undermined by severe social crises (Hayami and Godo 2004).

Such long-term dynamics between and within international regions do not seem to shake the presumption of unconditional convergence in (higher) labour productivity of the neoclassical growth theory (Rodrik 2013) or new structural economics (Lin 2011), regardless of today's disturbing ground realities in terms of human life (billions of people still in extreme poverty, rising inequalities) and its fi nite support (depletion of natural resources). This belief in the long-term convergence of free-market economies is rooted in the paradigm of "structural transformation" that shaped economic thought after World War II (Johnston and Mellor 1961; Chenery and Srinivasan 1998; Herrendorf et al 2014), and which refers to the reallocation of economic activity across three broad sectors: agriculture, industry and services. This paradigm is anchored in conceptions and measures of economic development according to three sectors ("primary," "secondary," and "tertiary": A G B Fisher, C Clark, J Fourastié), in some historical experiences of "modern economic growth" (Kuznets 1966), and in dual economy models inspired by Lewis (1954) of interrelated structural changes between the "subsistence" sector (elsewhere than in Lewis: agricultural, rural, traditional, informal, etc) and the "capitalist" sector (or non-agricultural, modern, urban, formal, etc).

From all this literature emanates a development model where agriculture provides cheap labour to propel the process of industrialisation and urbanisation, which in turn deliver technology and increasingly cheaper industrial inputs that increase agricultural yields and allow people to be fed at ever lower costs. After a turning point, until which the intersectoral differential in labour productivity actually widens (Kuznets curve), agricultural labour productivity should rise and poverty be eliminated. In the process, the share of household expenditure on food staples declines (Engel's law), while outlay on manufactured food, other industrial goods and services rises, until we reach the stage of a "world without agriculture" (Timmer 2009), as in the now-rich OECD countries. In the latter countries, the share of agriculture in both total employment and value added is now 2%–3%, while labour productivity across the agricultural and non-agricultural sectors has converged: historical rural mass poverty has been eradicated.

The question that arises is whether one day this kind of historically dated structural transformation that has occurred in a few countries (less than one-third of the world population in 2007) can really take place elsewhere, or at what financial, social and environmental costs. In the OECD countries, what actually boosted farm labour productivity and its convergence with non-farm productivity was large-scale mechanisation of agriculture rather than yield increase (Dorin et al 2013). Can densely populated regions such as India and Africa experience a similar phenomenon one day? It is very unlikely since such large-scale mechanisation of agriculture would require an off-farm migration and a concomitant mega-urbanisation unprecedented in human history.[8] Instead, due to the convergence of increasingly lower labour-intensive manufacture all over the world (Rodrik 2013) and cities that are often already congested, the bulk of the workforce remains trapped in subsistence agriculture (a lesser evil?) with insecure casual off-farm jobs whenever they can be found. As a result, even if the share of farmers in the total working population is slowly decreasing, the numbers of farmers may continue to increase as observed in the past in most developing regions of the world (Figure 9).[9] This increase in the agricultural workforce then proportionately reduces the already small size of farms in regions where agricultural land is finite, and the resulting fragmentation (less available land per farmer) can only be compensated by higher increases in crop yield or animal husbandry. This is a challenging situation, especially if land productivity relies on an intensive use of inputs with high financial and environmental costs (chemical fertilisers, pesticides, lab-seeds, fuels, and irrigation). Asia, especially India, has had to face the reality of this challenge throughout the last decades (Dorin et al 2013; Dorin and Aubron 2016) with (i) average land availability per farmer decreasing whereas it was already at the lowest world level in the early 1960s, (ii) average land productivity increasing faster than elsewhere to maintain or enhance farmer labour productivity, but (iii) natural capital (water, soil, and biodiversity) declining faster than elsewhere, and (iv) the productivity gap between farm and non-farm labour diverging rather than converging.

Such an "Asian trap" or "Lewis trap" was not anticipated by Yujiro Hayami and Vernon Ruttan in the 1970s. They told us that mechanisation was the key technological instrument to augment farm labour productivity in the land-abundant Western countries (the United States in particular), whereas it was water and modern agricultural inputs in the land-constrained and labour-abundant Eastern countries (Japan in particular) (Hayami and Ruttan 1971). But, obviously, despite huge investments in irrigation and modern agricultural inputs in Asia since the 1960s (green revolution), population pressure on land resources could not be circumvented so easily, contrary to what the two agricultural economists predicted, and farm labour productivity has not increased "up to the levels of Western Europe in the early 1960s" (Ruttan 2002). There has not been a rapid economic catch-up, but rather the opposite: in our reference scenario, the average Asian agricultural labour productivity in calories in 2050 would still be 1.5 times lower than that of Western Europe in 1961, and in 2050, it would be 65 times lower (Figure 10). Could a major breakthrough in biotechnology help reverse such a trend as some, especially the seed multinationals, believe or claim? As in the 1960s or the 1970s, biotechnology can still be unconditionally trusted to eradicate poverty, but, for the time being in India, after 50 years of heavy investment in the high-yielding varieties of the green revolution, incremental yield per unit of inputs is declining, surface water conflicts are increasing, water tables dropping, input costs rising, and farmers' distress is being transformed into political slogans.

Accelerated part-time farming with rural non-farm jobs can certainly relax current agrarian tensions in Asia, especially India (Binswanger-Mkhize 2013), along with policies to make land rights transparent and the judiciary accountable (Gupta and Giri 2016). However, accelerated part-time farming may also mean accelerated "semi-proletarianisation" (Yadu and Satheesha 2016), and, all in all, it should not radically change the global equation. In fact, in SSA and even more so in Asia, the amount of available land for agriculture, in comparison to the size of the current or future populations could make it extremely difficult—if not impossible—to replicate the development path followed by today's industrialised countries. Unless we envisage a free (and truly massive) movement of labour at an international scale, as is more or less the case for capital today. For the moment, such an assumption helps economic theory find a long-term universal wealthy equilibrium through mathematics. But on terra firma, this option is not on any short- or long-term political agenda, especially in wealthy countries that find it difficult to welcome several hundred millions of destitute people for the sake of convergence in labour productivity.

Conclusions

Our study incites us, in fine, to reconsider our "modern" model of increasing land and labour productivity in agriculture. This model could, in fact, be too circumscribed within the historical and geographical contexts that brought it into being.

Future avenues, maybe, lie in a new science and technology paradigm, or a new sociotechnical regime (Schot and Geels 2007) where an increase in agricultural productivity does not rest, above all, on a few large-scale monocultures (harvested by very few or a plethora of farmers) and with intensive use of water, fossil fuels, and agrochemical inputs (especially by small-scale farmers), but rather on a context-specific agroecosystem that boosts biological synergies below and above ground, amongst numerous plant and animal species (from soil fungi to trees, from soil bacteria or worms to cattle, etc). Boosting biodiversity and ecological functions in each unique agroecosystem are highly complex and require marrying the best science with traditional indigenous knowledge.

But, compared to the current technocentric modern agriculture, in the long run it is likely to be (i) more productive per unit of land, (ii) more resilient to climatic or economic shocks, (iii) more labour-intensive than capital-intensive, and (iv) more profitable for farmers if commodities of higher quality (diversified tasty nutritious food, pesticide-free products, etc) and ecosystem services of local and global importance (safe water, carbon and biodiversity pools, soil fertility, nutrient recycling, pollination, disease and flood control, climate mitigation/adaptation) are equitably priced on local and international markets (Dorin and Hourcade 2012; Dorin et al 2013). "Ecological intensification" or "agroecology," which is also a political or social movement (Wezel et al 2009), seems to recommend this path but a lot remains to be done before the current sociotechnical regime can be redirected from a supply-driven, genetics-led production system towards an agroecological knowledge-based bio-economy that augments location-specific human and natural resources (Altieri 1999, 2009; Bommarco et al 2013; Garibaldi et al 2016; Gliessman 2007; Griffon 2013; IFAD and UNEP 2013; IPES-Food 2016; Jansen 2015; Kumaraswamy 2012; Levidow et al 2013; Martinez-Torres and Rosset 2014; Perfecto and Vandermeer 2010; Reganold and Wachter 2016; Tansey 2013; Vanloqueren and Baret 2009).

Instead of a sequential development trajectory, where incomes and labour shift or rise from predominantly agrarian, to industrial, to service sector-led growth that seems out of reach for both India and SSA, why not immediately embed agriculture in both the primary and tertiary sectors, via a mosaic of highly productive and labour-intensive agroecosystems providing diversified quality products along with ecological and social services of multi-scale importance and value? Working more effectively with local agroecosystems could also considerably increase local employment opportunities in the secondary sector (manufacture of agri-inputs or processing and marketing of agri-outputs) and overall prevent the Indian states and African countries from converting their demographic dividend into a debt (Desai 2010). Beyond their biophysical and socio-cultural differences, India and SSA could look more closely at this avenue, and lobby to direct research and market incentives towards this track, possibly in partnership with France, which has great ambitions in the area of agroecology (Le Foll 2014), and other European countries concerned with creating rural employment and other social, economic, and ecological landscapes than large-scale and over-indebted farms (Schuh et al 2016). This avenue demands massive investments in various fields, but it also, and maybe primarily, presents an institutional challenge that involves discovering a meeting point for different goods both in national and international markets. On the one hand, the generic industrial agricultural products that now feed a large part of humanity with their upstream and downstream oligopsonic and oligopolistic powers and, on the other hand, territory-specific agroecological products that have a very different economic, social and ecological content. This opens up a wide spectrum of research for economists. In the absence of this research, they could merely estimate the cost of safety nets that would need to be developed between now and 2050 in order to ensure the survival of the hundreds of millions of people living in the countryside or in mega urban slums in Asia and Africa.

NOTES

1 ASIA (Asia), EU30 (European Union with 27 countries + Switzerland, Norway, Iceland), EU08 (other Western European countries, Ukraine included), LAM (Latin America), MENA (Middle East and North Africa), NAM (North America), OCEA (Oceania) and RUSS (Russia and Central Asia). On the reasons for and limitations of this regional partition, see Annex 1 in Bruno Dorin (2014a); the partition was partly constrained by geographical aggregates in the FAO data sets, such as "OEEU" which gathers Albania, Bosnia and Herzegovina, Croatia, Macedonia, Serbia and Montenegro, Byelorussia, Moldova and Ukraine.

2 We present and discuss the methodology we used to obtain our reference scenario "PAB50" in Dorin (2014a, 2014b). Basically, to obtain comparable estimates for the whole period 1961–2050, we applied to our Agribiom values for "2006" (three-year average 2005–07) in different fields (population, surface, yield, trade, consumption, etc) the growth rate calculated with the data sent by the FAO for "2006" (three-year average 2005–07) and 2050, after their conversion and aggregation into calories whenever relevant.

3 Seasonal and perennial crops.

4 Our estimates of food availability per capita result from calculations, they can be compared throughout the period (1961–2050), but they do not necessarily match those of the FAO, either for the past (1961–2007) or in its projection exercise (2006, 2050); generally, our results are slightly above the official FAO data on food availability per capita.

5 Ratio of independence in food biomass = ($\text{Production}_{VEG} + \Phi \text{Production}_{ANI}$) / ($\text{Consumption}_{VEG} + \Phi \text{Consumption}_{ANI}$) with $\Phi = 2.75$, the world average according to our estimates; see Dorin (2014b), Dorin and Le Cotty (2012) or Le Cotty and Dorin (2012) for details and a discussion on this issue.

6 See notes below Table 1 for clarifications.

7 See note 1, Table 1, for an illustration. That said, while in Agribiom we use uniform coefficients across countries (and years) to convert tons of products into calories, this is not the case in the FAO food balance sheets (from 1961) nor in Alexandratos and Bruinsma (2012) where, for a product, the calorie content can vary greatly (for example, for maize: from 1.20–1.45 kcal/g in Russia and Canada, to 3.45–3.55 kcal/g in Bangladesh, Egypt, Nepal and Peru). These country differences greatly complicated our calculations as we wanted to conform as far as possible to the FAO scenario (Dorin 2014a: 16–17).

8 In Dorin et al (2013), we have broadly quantified what this could mean for India: see "Three scenarios for India by 2050," page 14. Very interestingly, Nitin Desai (2010) conducted a similar exercise up to 2050, using a simpler model but clearly showing how the conventional structural shift may lead to huge migratory pressures from five northern states, on the rest of India. It could of course be the same within sub-Saharan Africa (Vergne and Ausseur 2015), but our own scale of analysis can only highlight huge migratory pressures from Asia or Africa to the rest of the world.

9 Estimating active population in agriculture is a tricky exercise, and FAO country-wise estimates (based on ILO estimates, themselves based on national statistics) are regularly questioned. FAO's figures on the "economically active population in agriculture" may be overestimated, particularly in Asian countries, due to a high rate of farmers with part-time off-farm employment. Even if other active populations classified in industry or services may also be part-time farmers (which then minimises or even compensates the plausible overestimates in agriculture), national statistical systems in Asia and Africa need serious improvements on such an important economic issue. For France, the FAO seems to report the number of annual work units (AWU) spent in agriculture by professional farmers, either self-employed or salaried. These AWUs are lower than the number of professional family farmers since in 2010, for instance, only 50% of them declared themselves as working full time in agriculture (Grandjean et al 2016). According to the FAO data, the availability of cultivated land (that is, agricultural land less pasture) per economically active agricultural worker is 33.5 ha as against 0.64 in India (that is, 52 times less than in France) in 2010–11 (year of the agricultural census in both France and India and from which the FAO data are drawn).

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